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TECHNICAL REPORT
66-37-FD

EDIBLE COATINGS FOR DRIED AND COMPACTED FOODS: PART I

by

Morton S. Cole

Archer Daniels Midland Company
Minneapolis, Minnesota

Contract No: DA19-129-AMC-102(N)

April 1966

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

US ARMY MATERIEL COMMAND

Food Division
FD-47

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FOREWORD

Experience with the dehydrated food components of operational feeding systems points to the desirability of increased protection against recognized environmental hazards such as prolonged exposure to atmospheric oxygen and humidity and against fragmentation, erosion and other manifestations of mechanical damage frequently encountered during handling and transport. Consideration of various measures likely to be effective against these diverse risks has focused attention on the potential efficacy of edible coatings. Such coatings have been widely used in the pharmaceutical and confectionery industries. Recent developments involving gums, pectin-base materials, acetylated glycerides and amylose films point to the probability that edible coatings and films will find increased application in the food industry.

As Part I of the investigation on edible coatings for dehydrated food, this report emphasized the development of edible coatings or films for protection against atmospheric moisture and/or oxygen, as a preventive of breakage and erosion, and as a deterrent to growth of mold. Films were tested for physical prerequisites; those showing promise were applied to compressed bars prepared from representative dehydrated foods for further evaluation. Part II of this investigation is scheduled for reproduction at a later date. It is concerned primarily with the application of coating a number of representative food items under simulated commercial conditions. The foods thus coated are subjected to storage tests and subsequently evaluated.

This investigation was conducted at the research Center of the Archer Daniels Midland Company, 10701 South Lyndale Avenue, Minneapolis, Minnesota under contract DA19-129-AMC-102, with funds provided by the project titled: Combat Feeding Systems. Dr. Morton S. Cole served as Official Investigator; he was assisted by John Daugherty and Rita Paska. The Project Officer for the U.S. Army Natick Laboratories was Dr. Maxwell Brockmann of the Food Division, Alternate Project Officer was Mr. Philip B. Warnock of the Container Division.

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ABSTRACT

Studies are presented on the development of edible barrier materials, their application to dehydrated foods and evaluation under accelerated storage conditions, effects of atmospheric oxygen and moisture, fragmentation and abrasion, and attack by microorganisms.

The most effective coating materials include hot melts of acetoglycerides and echylcellulose; mixtures of monoglycerides and polyglycolesters; protein films including soy proteinate and gelatin; fatty esters of amylose; monoglycerides; hard fats; and combinations of these materials in the form of laminates or mixtures.

Approved chemical preservatives, including sorbic acid, potassium sorbate, methyl and propyl p-hydroxybenzoates were effective in retarding mold growth when incorporated in coating formulations.

INTRODUCTION

The research performed under the present contract has been concerned with the development of edible films and coatings designed to protect dehydrated foods against the effects of atmospheric oxygen and moisture, fragmentation and abrasion, and attack by microorganisms.

In meeting these objectives, coatings must not interfere unduly with rehydration of dehydrated foods nor constitute more than 16% of the weight or volume of the coated food. Coatings must be composed of materials which meet the requirements of the Food and Drug Administration for human consumption and should contribute at least 3.5 kg. cal. per gram. Coatings should maintain their barrier properties over a wide temperature range.

The approach used in this study was to screen readily available, FDA approved ingredients for their structural and barrier characteristics. Materials which evidenced useful characteristics were combined in mixtures or laminates.

During the final portion of the contract period, the best available barriers were applied to dehydrated foods which were placed in accelerated storage under a variety of conditions.

The evaluation of barrier materials, the methods used for their application to dehydrated food products and their effect on the stability of dehydrated foods comprises the present report.

SUMMARY

A number of edible coating compositions have been developed which exhibit good moisture and oxygen barrier characteristics. The most effective coating materials include hot melts of acetoglycerides and ethylcellulose; mixtures of monoglycerides and polyglycerol esters; protein films including soy proteinate and gelatin; fatty esters of amylose; monoglycerides; hard fats; and combinations of these materials in the form of laminates or mixtures.

Fragmentation of freeze dried foods was significantly reduced or completely eliminated by thermoplastic coatings. The nature of the food product and the type of coating are more important factors than the temperature at which fragmentation occurs.

Thermoplastic lipid coatings were only slightly effective in limiting moisture uptake by coated foods stored at 80-90% RH. The method of application of the coating and the surface texture of the food appear to be important factors in the effectiveness of coatings.

Films selected as oxygen barriers do not perform equally well over the wide range of temperature and humidity conditions studied. Films of unplasticized gelatin ruptured at high temperature and low RH. A laminated film of acetoglyceride and soy proteinate was effective only at high temperature and high RH. A laminate film of gelatin and monoglyceride shows excellent oxygen barrier properties at 80-90°F but not at 25°F. A three-layered laminate of amylose laurate, soy proteinate and acetoglyceride performs well except under conditions of low temperature and low humidity.

Films which exhibit good oxygen barrier properties did not necessarily protect foods under comparable conditions. A laminate of acetoglyceride and soy

proteinate protected freeze dried carrots against color loss under conditions of high temperature and RH where the isolated film evidenced good oxygen barrier characteristics. Shelled Brazil nuts coated with gelatin, on the other hand, were not protected against oxidation under conditions of temperature and humidity where the film itself performs well.

Laminated films designed to protect against the combined effects of moisture and oxygen afforded slight, if any, protective effect against moisture uptake at high temperature and high humidity conditions. A laminate of amylose laurate, soy proteinate and acetoglyceride protected the color of freeze dried carrots at 80-90°F and 82% RH as well as 25°F and saturated RH. The coating was not effective at low humidities. A laminate of gelatin and monoglyceride reduced the moisture uptake by apple slices stored at 80-90°F and 82% RH. The degree of protection was slight and the coating did not prevent the occurrence of browning.

Coated foods stored at 80-90°F and >70% RH exhibited surface mold growth within two weeks. Approved chemical preservatives, including sorbic acid, potassium sorbate, methyl and propyl p-hydroxybenzoates were effective in retarding the growth of molds when incorporated in coating formulations. Preservative coatings were most effective in combination with foods having a natural preservative such as the salt content of salami or the sugar concentration of dates.

Organoleptic evaluations of coated foods stored for three months at 0° and 100°F indicate many coatings protected flavor and color to some extent. Chemical indices of deterioration did not always agree with organoleptic evaluations. Freeze dried chicken coated with amylose myristate/soy proteinate laminate developed a high peroxide value after three months at 100°F but oxidized flavor

was not evident in the rehydrated product. Flavor of chicken stored at 100°F was protected by a 50:50 blend of polyglycerol ester and monoglyceride. This coating also exhibited some protective effect on freeze dried pork but did not protect strawberries.

The flavor of peas was partially preserved at both 0° and 100°F by coating with soy proteinate or a laminate of amylose myristate and soy proteinate.

The color of freeze-dried carrots stored at 100°F was partially protected by laminated coatings but the quality of the rehydrated product was poor.

The moisture content of coated foods increased to a greater extent during three months storage at 0° than at 100°F and ambient humidity.

Coated foods generally rehydrate to at least 70-80% the extent of uncoated foods within 15 minutes at 180°F. Coatings which include acetoglycerides or polyglycerol esters are more resistant to hydration than other coating materials. Foods stored at 0°F for three months rehydrated to a lower extent than foods which were stored at 100°F.

EXPERIMENTAL METHODS

Preparation of Films

1. Film Casting

Film-forming material is dispersed in a suitable solvent. A 9" Baker variable film applicator (Gardiner Laboratories Inc.) was used to obtain a 10 mil wet film thickness. Films were cast on 10 x 14 inch chrome plated ferrotype plates or an 8½ x 11 inch polyethylene coated paper. The paper or ferrotype plate is held on a vacuum plate while the film is being cast. Cast films are dried at approximately 75°F and 50% RH.

2. Hot Pressed Films

Some of the protein materials studied were made into films by pressing a molding powder in a hydraulic press equipped with heated plates. Molding powders containing protein, water and plasticizer were spread between ferrotype plates and pressed for 4 to 7 minutes at temperatures of 250 to 300°F and a pressure of 3200 psi on a 4 inch diameter ram.

3. Unsupported Thermoplastic Films

The barrier characteristics of unsupported lipid films were determined by coating fiber glass screen containing approximately 64% open area with the melted lipid or other thermoplastic material. Discs of the coated screen were used in appropriate test cells for moisture vapor and oxygen transmission. The thickness of the coated screen was 17-19 mils.

Physical and Chemical Tests

1. Tensile Strength

The tensile strength of unsupported films was determined by means of

ASTM D 882-56T performed on an Instron Model TT-C Universal Testing Machine.

2. Elongation

Percentage elongation was calculated from tensile strength data at the break point.

3. Tear Test

Resistance to shear of unsupported films was determined by the ASTM D 1004 tear test performed on the Instron machine.

4. Moisture Vapor Permeability

Constant temperature and humidity conditions were maintained in a chamber by bubbling compressed air through a pan of water. Temperature was controlled by means of two 100 watt light bulbs operated through a Fenwal switch. Relative humidity was determined by means of a Minneapolis Honeywell Model W611A portable relative humidity indicator. Chamber conditions were maintained at 32°C and 95% RH without load and approximately 90% RH with load.

Sample cells were constructed from 3 inch diameter by 1 inch brass weighing cans with friction lids. A 2-3/8 inch diameter window was removed from each lid to give 4.4 square inches of exposed film surface. Films were sealed to the inside of the can tops by means of plastic cement.

Each weighing can was filled with 15 g. of anhydrous $CaCl_2$ and covered with the lid containing the test film. The center joint of the weighing can was sealed with plastic tape. Cans were weighed and placed in the humidity cabinet. After 24 hours, cans were reweighed and moisture vapor transmission calculated per square inch of exposed film surface.

5. Oxygen Permeability

Oxygen permeability of films was determined by the method of Karel *et al.* 1/

1/ Food Technology 17, 91-94 (1963)

Permeability measurements were based on the amount of gas which diffused through the test material under conditions in which the total pressure differential across the film was zero and the oxygen partial pressure differential was one atmosphere.

Test cells used were as described by Karel et al. [1] A series of connected test cells permitted the simultaneous evaluation of up to 6 films. Films were mounted in the cells between two neoprene gaskets which prevented leaking of the cells at pressures up to 4 atmospheres.

To avoid changes in pressure in the cells when samples were withdrawn, 1 ml. of nitrogen was injected into the test compartment through an injection port prior to withdrawing 1 ml. of sample. Up to 10 samplings could be made in the same test cell without affecting the accuracy of the determination.

A dual column, dual detector Fischer Model 25V Gas Partitioner was used to measure oxygen concentration in the test cell. Operating conditions were:

Sample	1 ml
Column Temperature	Ambient, 75°F
Carrier Gas	80 cc. helium/min
Recorder	5 mv Sargent Strip Chart
Sensitivity	10 ul O_2 at 7 ma filament current
Retention Times	Oxygen 71 seconds
	Nitrogen 97 seconds

The permeability constant of films was determined from the formula

$$P = Yxc/tp$$

where P is the permeability constant expressed in units of $\frac{\text{cc mils}}{\text{day } m^2 \text{ atm}}$;

Y is the cell constant and is the ratio of the cell volume to the area of the film; x is film thickness in mils; c is the volumetric percent concentration

of oxygen in the sample; t is time in days and p is the partial pressure difference, in atmospheres, of oxygen across the film.

6. Fragmentation

A pyrex glass battery jar measuring $8\frac{1}{4}$ inches in diameter by $9\frac{1}{2}$ inches in height was fitted with a fiber glass baffle $3\frac{1}{2}$ inches wide and running the height of the jar. A weighed sample is placed in the jar and the opening sealed with Saran film. The jar is rotated on ball mill rollers at a rate of 35 RPM for 10 minutes. At each revolution, the sample pieces are picked up by the baffle and dropped through a distance of approximately 8 inches. After 10 minutes, samples are removed onto nested USBS #4 and #8 sieves and the percentage retained on each screen is determined.

Where fragmentation studies were to be made at 20-30°F and 80-90°F, both samples and the glass jar were equilibrated within these temperature ranges and the test performed quickly at room temperature.

7. Equilibrium Relative Humidity

ERH of coating materials was determined by a method similar to that described in Quartermaster Research Project Report #1 for Contract DA 19-129-AMC-11 (X) A349. Quart Mason jars were used as constant humidity chambers. Humidity was controlled by use of standard solutions (ASTM E 104) Samples were placed in a $1\frac{1}{2}$-inch length of aluminum pipe of $1\frac{1}{2}$-inch O.D. and 0.035-inch wall thickness weighing approximately 15 g. The tube containing the sample was suspended from the lid by a wire wrapped around the aluminum tube, projecting through a small hole in the lid of the jar and ending in a hook. It is thus possible to weigh the aluminum sample holder and contents without removing the sample from the jar.

Solutions used to obtain known relative humidities included:

Sulfuric acid Sp.g. 1.647	2.5% RH
Sulfuric acid Sp.g. 1.498	22% RH
Potassium carbonate	43.7% RH
Sodium chloride	75.8% RH
Glycerin 12% in water	98.4% RH

Humidity chambers containing samples of films were stored in a constant temperature room at 75°F. Samples were weighed at weekly intervals until samples came to equilibrium. Equilibrium was attained in most cases in 2 to 3 weeks.

8. Moisture

Moisture content of freeze-dried and other foods was determined by the Karl Fischer titration method.

9. Oxidation

The oxidation of fat-containing foods was determined by the AOCS peroxide method.

Carotene oxidation in freeze-dried carrots was determined spectrophotometrically after chromatographic separation of β-Carotene on a column containing equal parts of Hyflo Supercell (Johns-Manville) and Seasorb 43 activated magnesia (Westvaco Chlorine Products Company). β-Carotene was eluted from the column with 90:10 Skellysolve B:acetone mixture. Using this solvent as a blank, the optical density of the eluate was determined at 436 mμ.

The oxidation of freeze-dried peas was determined by a decrease in the concentration of chlorophyll. The ground sample is extracted with a 90:10 mixture (V/V) of 99% isopropanol and water in an extraction thimble. The absorbance (A) of the extract is determined at 665 mμ on a Beckman DK-2. The absorptivity (a) is calculated by the formula:

$$a = \frac{A}{\text{sample concentration g/l}}$$

the chlorophyll index = 100a

Application of Coatings to Foods

Spray Application

Apparatus for spraying materials on foods consisted of a pneumatic atomizing nozzle (Spraying Systems Co. spray setup number 13A), a DeVilbiss pressure pot of one quart capacity and a tubular heat exchanger for heating the air. The pressure pot containing the coating material was placed in an electric heating mantle so that thermoplastic materials could be kept molten. Delivery lines were wrapped with electric tape to prevent plugging. Air lines were equipped with reducing valves and gauges to control both liquid and air pressure. It became necessary to use a steam jacketed nozzle to prevent the solidification of thermoplastic materials at the tip of the nozzle.

Thermoplastic coatings solidify soon after emerging from the nozzle. They deposit on food materials in the form of a powder or beads. A continuous coating is formed by heating the spray coated food under a heat gum.

Freeze dried peas were spray coated with soy proteinate dispersions while held in a sieve. Small samples were sprayed while agitating the sieve. A stream of hot air from a heat gum is simultaneously directed onto the peas to evaporate the moisture before it can penetrate into the pea.

Preformed thermoplastic films composed of ethylcellulose-acetoglyceride formulations were placed on the larger food samples such as blocks of freeze dried fish, scrambled eggs and fruit cake. The seams of the film were welded together with a fine jet of heated air.

Amylose ester coatings were applied by spraying or dipping foods into a hexane dispersion of the fatty amylose ester, followed by volatilization of the solvent.

Laminated films for chemical and physical evaluation procedures were prepared by casting superimposed layers of different film forming agents. The base layer was cast on polyethylene coated paper or on chrome plated ferrotype plates. In applying laminates or superimposed layers to foods for storage studies, several successive coatings were applied by spraying or dipping. Aqueous dispersions of protein oxygen barriers were applied on top of a primary moisture barrier layer to prevent transfer of moisture into the dehydrated food.

Storage of Coated Foods

Coated foods were stored in 400 ml polyethylene beakers which were drilled with 1/4 inch diameter holes. Environmental conditions for storage were as follows:

1. 70-75°F 80-85% RH (Table 11)
2. 25 $\pm$ 2°F $<$ 20% RH--storage in covered mason jars containing anhydrous $CaCl_2$ (Table 16,24)
3. 25 $\pm$ 2°F $>$ 70% RH--storage in freezer cabinet with saturated atmosphere (Tables 16,23)
4. 80-90°F $<$ 20% RH--storage in mason jars containing anhydrous $CaCl_2$ (Tables 16,22)
5. 80-90°F $>$ 70% RH--storage in humidity cabinet at 82% RH (Table 16,21)
6. 0°F saturated atmosphere (Table 27)
7. 100°F ambient humidity (Table 27)

RESULTS AND DISCUSSION

Coating Development and Evaluation

A variety of edible, film-forming materials were screened for characteristics that would be suitable to the requirements of the contract. Categories of coating materials and their evaluation are described below.

Amylose Films

Amylose films were prepared by coating aqueous dispersions of high-amylose starch (American Maize ARD 1480) on polyethylene coated paper. The standard procedure was to disperse 30 g of amylose in 164 ml distilled water. Plasticizer and other ingredients as indicated below were added and the dispersion was autoclaved for 30 minutes at 15 . .:. Ten mil wet films were drawn on polyethylene coated paper which was heated from below by means of a hot plate to a temperature of 60-70°C.

Amylose films were plasticized with various levels of glycerol. Other additives to the amylose dispersions included slow-set pectin, gelatin, acetylated monoglyceride (Myvacet 5-00), and a confectioner's hardened coating butter (Wecobee HLS).

Amylose films exhibit moisture vapor transmission (MVT) ranging from approximately 0.5 to 1.2 grams per square inch of exposed film surface in 24 hours depending on the specific formulation (Table 1). Increase in glycerol plasticizer results in increased MVT. A commercial sample of thermoplastic amylose film exhibits an MVT of approximately 0.7 g/sq in/24 hrs. Hydrocolloids such as gum arabic, pectin and gelatin do not markedly affect the MVT of amylose films. Amylose films containing hydrocolloids appear to dry and crack readily at 120°F. Higher levels of glycerol plasticizer improve amylose film stability at 120°F. The addition of a fat

(Wecobee HLS) to amylose in the form of a fine dispersion results in lowering the MVT and increasing the stability of the film at 120°F. Acetylated monoglycerides exhibited no such beneficial effect, possibly because of the poor dispersibility of this material in the amylose sol.

While amylose films are fairly strong (Table 3), water soluble, and stable over a wide temperature range, if properly formulated, they are relatively poor moisture barriers and must be dispersed in water in order to be applied to small pieces of dehydrated food material. Their contribution to an edible coating would be as a physical barrier to fragmentation and as a support for additional layers of coating. The application of an aqueous dispersion to the surface of freeze-dried foods would result in moisture transfer into the food unless the dispersion was applied to a previously deposited, moisture-resisting coating.

Pectin Films

Sodium polypectate (Sunkist) films were prepared from a dispersion containing 2.5% polypectate and 5% sucrose. Films were cast on polyethylene coated paper and drawn through a 10% $CaCl_2$ solution to set the film.

Low methoxyl pectin (Exchange) films were prepared from a dispersion containing 3 grams LM. pectin in 400 ml. water. The LM pectin dispersion is heated to 80°C and plasticizers such as glycerol and polyglycerol esters dispersed with agitation. Films are cast on polyethylene coated paper and drawn through 10% $CaCl_2$ to set the film.

Pectin films exhibit higher MVT than do amylose films. Pectin films dry out readily at 120°F and crack easily. Polyglycerol esters aid in reducing brittleness but the films are very sensitive to moisture and soften appreciably when handled. The problems involved in coating dehydrated foods with pectic

substances are comparable to those encountered with amylose films. Their fragility and poor moisture barrier characteristic do not commend their use as coatings for dehydrated foods.

Gelatin Films

Gelatin (Atlantic Type A, 250 Bloom) was combined with sodium alginate, polyglycerol esters, Carbowax (polyethylene glycol) and inorganic phosphate salts in various films. Gelatin films evidence about the same order of moisture vapor transmission as amylose films. Films containing sodium alginate were treated with $CaCl_2$ in an attempt to reduce the MVT. Polyglycerol esters and Carbowax incorporated in gelatin films reduced the moisture vapor transmission somewhat. Inorganic phosphate salts similarly appear to reduce the MVT of gelatin films.

Gelatin films are soluble in water. They remain flexible at freezer temperatures although they cannot be creased without breaking. Films dry out and become brittle at 120°F, showing the importance of moisture for plasticizing gelatin.

Soy Protein Films

Films prepared from soy flours (50% protein), 90% isoelectric protein and 90% proteinate exhibit slightly lower moisture transmission than does gelatin. Soya films were prepared by a hot press technique which probably denatures the protein. A low solubility in 180°F water was observed. Films merely soften, in some cases appreciable swelling occurs, without dissolving. These films remain flexible to some extent at -10°F but become quite brittle at 120°F.

Gluten Films

Vital wheat gluten films prepared by the same technique as soya films

exhibit higher moisture transmission than do the soy films. Gluten films maintain some flexibility at both -10° and 120°F. Gluten films soften appreciably in hot water and become fairly elastic.

Egg Albumin

Albumin film exhibits very high moisture transmission. Film prepared by the hot press method becomes very brittle at 120°F and softens in water but remains insoluble.

Sodium Caseinate

Sodium caseinate film cast from a 50% aqueous ethanol dispersion exhibits quite high moisture transmission. The film remains flexible at -10° and 120°F and is quite soluble in water. Moisture transmission of film can be reduced by incorporation of polyglycerol ester.

Zein

Zein films cast from dispersions of propylene glycol have a lower level of moisture transmission than other proteins which were evaluated. Zein is insoluble in hot water but softens and tends to contract.

Lipid Coatings

A variety of lipids, including triglycerides, monoglycerides, acetylated monoglycerides, fatty acid, and fatty acid esters of amylose exhibit the lowest moisture vapor transmission values of the various categories of edible materials that were evaluated. None of the lipids form unsupported films with the exception of the fatty acid esters of amylose. The latter materials cast from a 20% dispersion in hexane are transparent, flexible and slightly elastic.

In addition to their moisture barrier characteristics, thermoplastic lipid materials have the obvious advantage of not requiring dispersion in aqueous media for application to freeze-dried foods. A disadvantage of lipids is their brittleness at low temperatures and their low softening points.

The combination of lipids with film-forming substances yields materials with structural strength as well as moisture resistance. Combinations of acetoglycerides with ethylcellulose (Tables 4, 5, 6) yield self-supporting coatings which exhibit a narrow range of moisture transmission over a wide range of compositions.

The fatty esters of amylose are thermoplastic, film-forming materials with a wide range of physical and barrier characteristics depending on the length of the fatty acid 1/. While these materials are not presently approved by FDA, sufficient information is available concerning their edibility to warrant their inclusion in this study 2/.

The laurate and myristate esters of amylose were of greatest interest because they are clear, thermoplastic, flexible over a wide temperature range and resistant to moisture transfer. The amylose esters used in this study were 80 to 90% esterified. A fully esterified amylose ester contains 3 mols of fatty acid per glucose residue.

Amylose myristate exhibits slightly lower MVT values than the laurate ester, probably because of the longer chain length of the myristate ester. The MVT of amylose esters approximate the values obtained for other lipid materials. While the amylose esters are insoluble in water, they soften and break in hot water and thereby allow dried foods to rehydrate.

1/ Gros and Feuge J. American Oil Chemists Soc. 39, 19-24, 1962

2/ Booth and Gros Ibid. 40, 551-553 1963

Beeswax exhibits the lowest MVT of any edible material evaluated. It will not form unsupported films and, like other lipids, it is brittle at low temperatures and soft at higher temperatures.

Laminated Films

Two approaches toward developing coatings whose essential properties are contributed by two or more components are, 1) form a homogenous mixture of the separate components and 2) make a laminated film where each component comprises a separate layer.

Continuous films in the form of laminates are found to be more effective barriers than are films composed of homogenous dispersions of two or more components. The MVT of mixtures of gelatin and acetoglycerides (Table 10) are closer to the MVT of gelatin than to acetoglycerides. Polyglycerol esters, which are more readily dispersed than acetoglycerides, reduce the MVT of gelatin. Similarly, dispersed fats reduce the MVT of amylose films. However, the MVT of laminated films where barrier layers are continuous, approach the MVT of the separated moisture barrier layer. The effectiveness of a barrier, therefore, depends on its continuity.

Laminates were made up of combinations of primary film-former, moisture barrier, and oxygen barrier. Tables 1,10 indicates that lipid materials exhibit the best moisture barrier characteristics. Proteins exhibit the best oxygen barrier characteristics of the classes of edible materials evaluated (Table 3). The ethylcellulose-acetoglyceride composition served as the base for some of the laminates. None of the laminates were completely soluble in 180°F water but all softened appreciably. Most of the laminates remained at least partially flexible over a wide temperature range (Table 1). Laminates containing amylose esters tended to become soft or sticky at 120°F.

Few of the films evaluated are completely soluble in water and aqueous chemical reagents (Table 2). Films cast from sodium caseinate, gelatin, and sodium soy proteinate were usually completely soluble. Protein films prepared by the hot press technique, including isoelectric soy protein, soy proteinate, albumin, and gluten films were resistant to water. Fatty amylose esters were the most water resistant of the films studied.

Protein films were generally more soluble at pH 9.2 than at 4.0, reflecting the lower solubility of proteins near their isoelectric points. Differences observed in the solubility of protein films in $CaCl_2$ and NaCl solutions are probably not significant in most cases.

Proteins do not increase in weight after immersion in oil and are therefore useful as fat barriers. Soy proteinate film plasticized with glycerol absorbed a large amount of oil. The plasticizer may have allowed the migration of oil into the film. Amylose myristate is completely soluble in oil while the laurate ester absorbs 2.5 times its weight in oil but remains intact. The ethylcellulose-acetoglyceride film absorbed only 1.5 times its initial weight in spite of its lipid contend. Laminates of lipids and proteins appear to be better barriers to the penetration of oils than the individual components of the laminates.

Gelatin and amylose films exhibit the highest tensile strength values (Table 3). Increasing levels of plasticizer reduce the tensile strength of gelatin films. Although ethylcellulose-acetoglyceride film exhibits low tensile strength, Tables 7 and 8 indicate this film is one of the most effective in resisting fragmentation. There is no apparent relationship between tensile strength and the ability of coatings to resist fragmentation.

Films and coatings vary widely in their permeability to oxygen at ambient temperature (Table 3). The lowest oxygen permeability is exhibited by unplasticized gelatin and soy proteins. Laminates containing soy proteinate also exhibit low permeability to oxygen.

The rate of oxygen permeability for various films is shown in Figures 1-9. Films such as zein, gluten, unplasticized gelatin, soy proteinate, soy flour, amylose, and ethylcellulose-acetoglyceride achieve a steady state. The length of time required and the concentration of oxygen in the test cell at a steady state condition indicates the effectiveness of the film as an oxygen barrier. The lowest levels of oxygen in the test cell are obtained with unplasticized gelatin and soy proteinate films (figures 3 and 4). Addition of plasticizer to gelatin films markedly reduces its effectiveness as an oxygen barrier (Figure 3). Soy proteinates, on the other hand, retain excellent barrier properties when plasticized (Figure 4).

The permeability of films prepared from soy flours by the hot press technique depends on the level of dispersible or undenatured protein (Figure 5). The oxygen barrier characteristic of some protein films may therefore be heat labile.

Films composed of ethylcellulose acetoglyceride hot melt are fairly poor oxygen barriers. The viscosity of the ethylcellulose appears to affect film permeability (Figures 6 and 7, Table 6). The high viscosity grades of ethyl cellulose exhibit lower oxygen permeability than lower viscosity ethylcellulose.

Lipid films cast on screen supports exhibit high permeability to oxygen. The rapid equilibration of oxygen concentration observed for monoglyceride and beeswax (Figure 9) is not considered to be the result of pinholes in the film since the oxygen content of test cells with ruptured films approaches 100%.

Coatings Developed to Reduce Fragmentation

Various coating materials were screened for their effectiveness in reducing fragmentation of graham cracker pieces cut into one inch squares.

The hot melt, ethylcellulose-acetoglyceride composition applied by brushing or as a preformed sheet was effective in reducing fragmentation. (Table 7). Emulsions of stearic acid, polyglycerol esters, fats and polyethylene glycol were least effective, probably owing to wetting of the cracker and weakening of its structure. Dispersions of shellac, gum arabic and alginate were also of little use in reducing fragmentation. These materials formed thin, brittle coatings which tended to flake off readily.

Thermoplastic materials such as acetoglycerides and polyglycerol esters applied by spraying formed a powdery deposit on the cracker which was melted into a continuous film with a heat gun. These materials reduced fragmentation to some extent but were not as effective as the ethylcellulose-acetoglyceride hot melt.

Freeze dried foods including sliced roast pork, diced chicken, fish squares, , and molded scrambled eggs were coated and tested for fragmentation as indicated in Table 8. Squares of fruitcake sliced 1/2 inch thick were similarly tested. Fragmentation tests were carried out on products equilibrated at temperatures of approximately 25°F and 85°F.

All of the coatings used to prevent fragmentation were thermoplastic since screening studies had indicated these materials were the most effective. The composition of coatings is as follows:

1. Polyglycerol ester plus acetoglyceride

   50% Drewpol 3-1-S (triglycerol monostearate)

   50% Myvacet 5-00 (acetylated monoglyceride)

2. Polyglycerol ester plus monoglyceride

   50% Drewpol 3-1-S

   50% Myverol 18-07 distilled monoglyceride

3. Ethylcellulose plus acetoglyceride

29.4% ethylcellulose (Dow, 48.0% ethoxy, 50 cps)

58.8% Myvacet 5-00

5.9% Drewpol 6-2-S

5.9% Drewpol 6-2-0

Of the coatings tested, the composition of ethylcellulose and acetoglyceride was most effective in preventing fragmentation at both low and high temperatures (Table 8). The other compositions provided some protection against fragmentation in comparison to uncoated controls, but did not prevent an increase in the number of pieces and the amount of fines passing through a USBS #8 mesh sieve.

The effectiveness of the coatings in resisting fragmentation under the test conditions was related to the nature of the food as well as the coating applied. Squares of dense, cohesive fruitcake showed little fragmentation even in uncoated samples. Freeze dried scrambled eggs were extremely fragile and shattered into many smaller fragments while being tumbled, even if coated. The ethylcellulose-acetoglyceride coating acted as a pouch in holding all of the broken pieces together. Freeze-dried strawberries subjected to the tumbling test did not increase in number of pieces, whether coated or uncoated. The amount of fines increased markedly, indicating the fragility of the freeze-dried strawberry.

Temperature at which the test was run had only a slight effect on the fragmentation of coated and uncoated foods under the test procedure. Table 8 indicates that the largest temperature effect is seen with coated freeze-dried strawberries. Slight fragmentation occurs at 20-30°F, while at 80-90°F, the amount of strawberry fines developed is approximately the same as the uncoated control. The greater effectiveness of the thermoplastic coating at lower temperatures may be attributed to the rigidification of the porous strawberry structure by the absorbed thermoplastic. At higher temperatures, the coating material softens and no longer supports the strawberry structure.

Freeze-dried foods coated to resist fragmentation were rehydrated in 180°F water and their increase in weight was determined at 5-minute intervals. The effect of coatings on the rate and extent of rehydration (Table 9) depends on the food, the coating and possibly on the method of application of the coating. A blend of monoglyceride and polyglycerol ester did not decrease the rate or extent of hydration of freeze dried chicken. A mixture of acetoglyceride and polyglycerol ester, on the other hand, reduced by almost half both the rate and extent of hydration of freeze-dried pork and strawberries.

Both the monoglyceride-polyglycerol ester coating and the acetoglyceride-polyglycerol ester coating were applied as a spray. The ethylcellulose acetoglyceride composition was applied as a preformed film to freeze dried fish sticks and scrambled eggs. The preformed film lies entirely on the surface of the food and when ruptured allows availability of water to much of the food surface. Hot melts applied as sprays with subsequent heating are drawn into the porous structure of freeze dried foods. The ethylcellulose acetoglyceride film allowed a 70% hydration of scrambled eggs and an 85% hydration of freeze dried fish sticks. An undesirable aspect of the ethylcellulose acetoglyceride film is its failure to dissolve or completely lose identity at the rehydration temperature of 180°F.

Coatings Developed to Decrease Moisture Uptake

Moisture Vapor Transmission

Edible, film forming materials were evaluated for their moisture barrier characteristics at temperatures of 20-30°F and 80-90°F (Table 10). Moisture vapor transmission measured at 80-90°F was generally from 4 to 10 times greater, and in the case of acetylated monoglyceride, 50 times greater than the MVT measured at 20-30°F.

Amylose laurate is noteworthy in that little difference in MVT was found between the high and low temperature ranges. Low MVT values at 80-90°F were also exhibited by a laminate of soy proteinate and acetoglyceride; a triple laminate composed of amylose laurate, soy proteinate and acetoglyceride; an ethylcellulose-acetoglyceride mixture; and a mixture of monoglyceride and polyglycerol ester.

The MVT of laminated films tends to approach the MVT of the separated moisture vapor barrier layer, which is either a fat or fatty ester. The MVT of 50:50 mixture of monoglyceride and polyglycerol ester is more nearly an average of the MVT of the individual components (Tables 1 and 10).

Equilibrium Relative Humidity

Equilibrium relative humidity (ERH) determinations indicate that triglycerides and fatty amylose esters are the only materials tested which do not increase in moisture content at higher relative humidities. The equilibrium moisture content of acetylated monoglyceride increases greatly above 70% RH. Polyglycerol esters and 50:50 mixtures of polyglycerol esters and monoglycerides exhibit equilibrium moisture contents between 5 and 10% (MFB) at 50% RH and moisture contents between 15 and 20% (MFB) at 80% RH. The longer chain polyglycerol ester (Drewpol 6-2-S) equilibrates at a higher moisture content than the triglycerol ester (Drewpol 3-1-S). Mixtures of polyglycerol esters with monoglycerides yields coating materials which equilibrate at low moisture levels below 60% RH.

Films prepared from gelatin and soy proteinate exhibit steep increases in moisture content with increasing relative humidity. Gelatin shows a greater increase in equilibrium moisture content at relative humidities below 40% than does soy proteinate.

The ERH of laminated and composite films (Figure 16) indicates multicomponent films are less sensitive to increase in moisture content than are the individual components. The ethylcellulose-acetoglyceride film and a three layer laminate composed of amylose laurate, soy proteinate and acetoglyceride do not increase appreciably in equilibrium moisture content at relative humidities up to 80%.

Storage Study

Food including freeze-dried diced chicken, air-dried sliced apples, freeze-dried sliced pineapple and graham crackers were coated as indicated in Table 11 and stored for 2 weeks at 70°F and 80-90% RH. Hot melt coatings were applied by spraying followed by heating in a stream of hot air to melt and distribute the coating. Amylose laurate was applied to freeze-dried pineapple by spraying the amylose ester in hexane solvent and volatilizing the solvent.

Table 11 indicates coatings applied to dried foods reduce moisture pickup only slightly under the storage conditions. Most of the coating materials became sticky during storage.

Acetylated monoglyceride appears to be one of the more effective coatings in spite of ERH data (Figure 13) and MVT data (Table 10) which indicate acetoglycerides are less effective moisture barriers than other lipid materials and that they can be expected to absorb moisture at high relative humidities. The confectionary fat, Wecobee HLS, applied to dried apple pieces is also somewhat effective as a moisture barrier. Amylose laurate, which appeared to have good potential as a moisture barrier based on ERH and MVT data (Figure 15 , Table 10), was of little use as a moisture barrier for freeze-dried pineapple.

The partial effectiveness of the acetoglyceride and fat may be related to the surface texture of foods. Both dried apples and graham crackers have a fairly regular, dense surface. Coating applied remains substantially on the surface and forms a barrier layer exterior to the food. Freeze dried pineapple, on the other hand, provides a very rough, creviced and porous exterior surface. Coating applied, especially in a solvent, is drawn into the food material and a much greater surface area is presented which must be coated to provide a continuous moisture barrier. Freeze-dried chicken similarly provides a porous, uneven surface.

Rehydration

Foods coated to resist moisture were rehydrated in 180°F water to determine the effect of coatings on the rate and extent of rehydration. None of the coatings tested interfered excessively with rehydration (Table 12).

Freeze-dried chicken coated with Drewpol 3-1-S exhibits a greater water uptake than the control which is attributed to the hydration of the coating.

Dried apple slices coated with a hard butter appear to hydrate to a higher extent than do apples coated with the monoglyceride-polyglycerol ester mixture.

Amylose laurate did not affect the rate or extent of rehydration.

Coatings Developed to Protect Foods Against Atmospheric Oxygen

Preliminary data (Table 3) indicates that protein films are the most effective oxygen barriers among edible materials. Protein films including sodium soy proteinate, gelatin and a laminate of sodium soy proteinate and acetoglyceride were evaluated for oxygen permeability at temperatures of 25°F and 85°F. and at relative humidities below 20% and above 70%.

Unplasticized gelatin film was an effective oxygen barrier under all conditions except high temperature and low humidity (Table 13). The latter conditions cause drying of the film which ultimately ruptures. Soy proteinate film exhibits relatively high oxygen permeability (Table 14) under all test conditions in spite of favorable early results (Table 3). The laminate of soy proteinate and acetoglyceride was an effective barrier only at high temperature and high relative humidity (Table 15).

Oxygen barrier coatings were applied to:

1. Freeze-dried carrot slices
2. Compressed potato chip bar
3. Freeze dried peas
4. Compressed yellow corn bar

Coated foods were stored at 20-30°F and 80-90°F and at relative humidi... under 20% and above 70% for a period of one month.

The results of this study (Table 16) indicate come of the coatings were of value although not over the entire range of storage conditions. The study at the high temperature and high humidity condition had to be curtailed in some cases because of surface mold growth.

The acetoglyceride-sodium soy proteinate coating had a protective effect on the oxidation of freeze-dried carrots at 80-90°F and 70% RH. This result correlated with oxygen permeability data (Table 15) showing the laminated film to have low permeability to oxygen under these conditions.

The soy proteinate film exhibits some protective effect on the compressed corn bar at the high storage temperature. At the low storage temperature, a higher peroxide value was obtained among uncoated controls at low R.H. than at higher humidities.

Potato chip bars coated with soy proteinate film exhibit spotty protective effects of the film at both low and high temperatures. The only agreement between performance of the film on corn and potato chip bars is at the high temperature and low humidity. The coating tended to dry and crack under low temperature and humidity conditions.

Unplasticized gelatin films which exhibited good oxygen barrier characteristics over a range of conditions (Table 13) had no apparent protective effect on coated Brazil nuts.

Freeze-dried peas spray coated with soy proteinate showed no increase in color stability in comparison to uncoated controls.

Freeze-dried peas coated with sodium soy proteinate rehydrate to the same extent and at the same rate as uncoated controls (Table 17). Freeze-dried carrots coated with acetoglyceride/soy proteinate laminate rehydrate to approximately one third the extent of uncoated controls.

Coatings Developed to Protect Foods Against the Combined Effects of Moisture and Oxygen

Materials that were found to be good oxygen barriers were combined with moisture barriers in the form of laminates. Coatings developed include:

1. Amylose myristate/soy proteinate
2. Gelatin/monoglyceride
3. Acetoglyceride/soy proteinate
4. Amylose laurate/soy proteinate/acetoglyceride

Moisture Vapor Permeability

MVT data (Table 10) indicates the films described above are good barriers at 20-30°F. Except for amylose myristate/soy proteinate, the films retain good moisture barrier characteristics at 80-90°F although MVT for all films increases by a factor of 2 to 20 times at the higher temperature. The gelatin/monoglyceride laminate exhibits the least change in MVT over the entire temperature range. The MVT of amylose myristate/soy proteinate laminate is about 10 times higher than the transmission of other coatings at comparable temperatures.

ERH determinations on laminated films indicate the combination moisture and oxygen barrier films equilibrate at a low moisture content below 80% RH (Figure [illegible]).

Oxygen Permeability

The amylose myristate/soy proteinate film exhibits low oxygen transmission characteristics at 80-90°F and above 70% RH. At other temperature and humidity ranges the film apparently breaks down (Table 20).

The gelatin/monoglyceride laminated film exhibits excellent barrier properties at 80-90°F and at both low and high RH levels, the permeability of the film increases considerably at 20-30°F and particularly at the higher relative humidity (Table 18).

A laminated film of soy proteinate and acetoglyceride exhibited low oxygen

permeability only at 80-90°F and above 70% RH (82% RH). High permeability was shown under other temperature and RH conditions. (Table 15).

A three-layer laminated film composed of amylose laurate/sodium soy proteinate/ and acetoglyceride showed low oxygen permeability under all of the test conditions except at low temperature and low RH. (Table 19). The film cracked under the latter conditions although the protein oxygen barrier layer was sandwiched between two moisture barrier layers to prevent drying of the protein.

Foods including freeze-dried chicken, freeze-dried pineapple, freeze-dried carrots, Brazil nuts, dehydrated apples and freeze-dried peas were coated with the laminated films and stored at 20-30°F and 80-90°F and at relative humidities below 20% and above 70% (Tables 21-24).

Freeze-dried diced chicken was coated with the amylose myristate/soy proteinate laminate. The amylose myristate in hexane solvent was applied first by dipping. Approximately 5.5% of amylose myristate was applied. The soy proteinate was applied by spraying a 20% dispersion of Promine D on top of the amylose laurate coating. The pieces were turned during spraying to expose all sides of the food particle to the spray. Following application of the Promine D spray, samples were air dried. Final coating weight represented approximately 9.1% of the dry uncoated food.

Freeze-dried sliced pineapple was spray coated with acetoglyceride. The aceto-glyceride concentration ranged from 13 to 20% on various batches. Acetoglyceride deposits as a fine powder on the pineapple. The powdery acetoglyceride is melted under a heat gun to obtain a continuous coating. The coated pineapple is then brush-coated with a 20% Promine D dispersion. The completely coated pineapple was air dried and a final coating concentration of 23-32% was obtained.

Freeze-dried sliced carrots were coated with three layers. Carrot slices were first dipped into a 6% dispersion of amylose laurate in hexane and the solvent vola-tilized off by heating at 150°F. The amylose laurate content ranged from 7.7 to 11.4%

of the food (uncoated basis). The amylose laurate coated carrots were then brush-coated with 20% Promine D dispersion and again dried. Finally the coated carrots were sprayed with acetoglyceride which was melted into a continuous coating with a heat gun. The final coating concentration averaged 16.8%.

Apple slices were spray-coated with monoglyceride. The coated apple pieces were brushed with a 20% dispersion of Type A 300 Bloom gelatin. The coated apples were dried in a warm air stream to a final coating composition of 18.3%.

Freeze-dried peas were dip-coated with amylose myristate dispersion in hexane. After volatilizing the solvent, the peas were sprayed with a 20% Promine D dispersion and dried. The final coating concentration was approximately 14%.

Rehydration of Coated Foods

Combination moisture and oxygen barrier coatings affected the rehydration of freeze dried foods as shown in Table 25 . Amylose myristate/soy proteinate laminated coating had almost no effect on the rate or extent of hydration of chicken. Freeze-dried peas with the same coating hydrated at a slower rate than uncoated controls and coated peas only hydrated to about 80% of the extent of the controls.

Pineapple coated with acetoglyceride/soy protein laminate hydrates to about half the extent of uncoated controls at 180°F. The 5-minute rate of hydration of coated pineapple is a third the rate of the control. The increased rate of hydration with time indicates the coating is gradually softened under the hydration conditions to a point where water can reach the food material.

Carrots with 3 layers of coating hydrates to half the extent of controls during the test period. The rate of hydration of coated apple slices, which initially is about a third the control rate, increases as the coating softens. At the end of the hydration period, the rate and extent of hydration of coated apples is approximately 20% below that of the uncoated control. The rate of hydration of coated freeze-dried peas similarly increases during hydration until it is only 10% below the control value.

Storage of Coated Foods

Dried foods stored at 80-90% relative humidity became moldy within 2 weeks at the higher storage temperature (Table 21).

Samples stored at low relative humidity at both low and high temperatures lost weight over the storage period. The low humidity condition was obtained by placing samples in sealed jars together with $CaCl_2$ dessicant. None of the coatings afforded a significant level of moisture barrier protection under high temperature and humidity conditions. At the low storage temperature and high humidity, the triple laminate of amylose laurate/soy proteinate/acetoglyceride protected freeze dried carrots from excessive moisture pickup and also provided some protection against carotene oxidation.

The amylose myristate/soy proteinate coating used on freeze-dried chicken appears to enhance the degree of oxidation under all storage conditions. An explanation for this observation may be the manner in which the amylose ester was applied. The hexane solvent used to carry the amylose ester could very possibly have dissolved the fat out of the chicken. Upon desolventizing, the fat could have been redeposited on the surface of the food, allowing greater accessibility to oxygen.

The acetoglyceride/soy proteinate laminate afforded little moisture protection under any storage condition. This coating was reversed and used on shelled Brazil nuts so that the soy proteinate oxygen barrier was the first layer next to the nut and the moisture barrier was the outside layer. The highest level of oxidation of Brazil nuts occurred under high temperature, high humidity storage conditions. The coating provided only very slight, if any, protection against oxidation. At the other storage conditions, there was only slight differences between coated and control samples both with respect to moisture uptake and degree of oxidation.

Dried apple slices coated with monoglyceride/gelatin laminate exhibit a lower level of moisture at the high temperature, high humidity storage condition than controls.

High moisture, coated apples lost moisture when stored at 25°F, at both low and high relative humidities.

Freeze-dried peas coated with amylose myristate/soy proteinate exhibit a greater level of oxidation at all storage conditions than do uncoated controls. The same explanation presented above in the case of chicken, the solubilization and redistribution of food lipids by the solvent carrier for the amylose ester, can be applied to peas. The coating failed to provide significant moisture protection for peas.

Essentially no correlation is seen between the barrier characteristics of the coating materials and their ability to protect foods against the combined effects of moisture and oxygen. The methods of coating application is certainly an important factor in the failure of these coatings to function as barriers.

Coatings Developed to Prevent Growth of Microorganisms

Edible, chemical preservatives, including sorbic acid, potassium sorbate, methyl p-hydroxybenzoate (methyl paraben) and propyl p-hydroxybenzoate (propyl paraben) were incorporated in coatings and applied to dry salami, date bar, Gouda cheese and white bread bar. Coated foods were stored at a temperature of 76°F and 84-87% RH for periods up to 18 days.

Slices of dry salami approximately 1/8-inch in thickness were coated with dispersions of soy proteinate (Promine D) containing 12 g of proteinate and 4 g of glycerol per 100 ml of water. Two preservatives, potassium sorbate and a 70:30 mixture of methyl paraben:propyl paraben were used at a level of 0.2% based on final product weight. Coatings were applied by dipping and constituted from 5-8% of final product weight. Five replicates of each treatment were evaluated.

Date bars weighing approximately 45 g were made from pitted dates pressed in a disc mold. The bars were $2\frac{1}{4}$ inches in diameter by $\frac{1}{2}$-inch in thickness. Bars were dip coated with acetoglyceride containing either propyl paraben or sorbic acid at a level to give 0.2% final concentration. The coating constituted 4% of the product weight.

Gouda cheese wedges weighing approximately one ounce were coated with the soy proteinate dispersions that were described above for coating salami.

White bread bars were prepared by compressing 36 g of crust-free commercial white bread in the disc mold at 300 . The bars, measuring $2\frac{1}{4}$ inches in diameter by $\frac{1}{2}$-inch in thickness were coated with a 5 mil film of acetoglyceride-ethylcellulose composition (51 F Table 6) containing 0.1% of methyl paraben, propyl paroben, and potassium sorbate.

Preservatives were effective in preventing growth of microorganisms after uncoated controls and coated foods without preservatives showed a large amount of growth (Table 26). The sorbates and parabens were equally effective in preventing growth

on salami and high sugar content in dates. This additional protection shows up in the greater elapsed storage time these foods withstand.

White bread bars and cheese were the most difficult foods to protect. Coating containing no preservative appeared to enhance surface mold growth.

Date b... stored under the high humidity conditions began to exude a thick syrup, even if coated. The exudate was probably a saturated sugar solution and no evidence of microbial growth could be found in it.

Microbial growth was almost entirely mold growth. Members of genus Penicillium and genus Aspergillus were identified.

Three-Month Storage Study of Coated Foods at 0° and 100°F

Coatings selected for application to freeze dried and other foods to protect against fragmentation, moisture pickup, oxidation, and the combined effects of moisture and oxygen were stored at temperatures of 0°F and 100°F for 3 months in combination with foods previously specified. Coated foods were evaluated for change in weight, moisture and organoleptic characteristics (Tables 27 and 28).

Fruit cake coated with preformed films of ethylcellulose-acetoglyceride composition (Table 6, 51F) exhibits the same level of moisture as uncoated control samples stored at 0°F and 100°F. The coated 100° sample lost weight within 6 weeks, then remained at constant weight.

Freeze-dried chicken pieces were coated with several coating materials including: polyglycerol ester (Drewpol 3-1-S); amylose myristate/soy proteinate laminate; and a 50:50 mixture of polyglycerol ester and monoglyceride (Myverol 18-00). Chicken pieces generally picked up moisture and increased in weight when stored at 100°F. The moisture content of all coated materials stored for 3 months at 0° ranged between 10 and 11%. Moisture content of samples stored at 100°F ranged from 2 to 4%. Both the amylose myristate/soy proteinate laminate and the monoglyceride-polyglycerol ester mixture protected chicken flavor and, in some instances, color. Polyglycerol ester

has a slight sweet flavor and dark color. It is believed that the changes in polyglycerol ester coated foods are caused by the coating alone.

Graham crackers coated with acetoglyceride and with preformed ethyl cellulose-acetoglyceride film did not differ significantly from uncoated controls in moisture content or weight change after 3 months storage.

Freeze-dried scrambled eggs coated with ethyl cellulose-acetoglyceride film increased less in moisture content than uncoated controls. The control samples stored at 100° developed a browned color and flavor. The coated sample also browned during storage. 0° storage samples retained acceptable color and flavor.

Compressed corn bars coated with soy proteinate increased in moisture content when stored at 0° to a greater extent than did the uncoated control. The soy proteinate film protected the corn bar from oxidizing to the extent of uncoated controls. In spite of a low peroxide value, the 100°F coated samples were faded in color as was the uncoated control.

Compressed potato chip bars coated with soy proteinate picked up more moisture when stored at 0°F than did controls. The coating provides some protection against oxidation of samples stored at 100°F. At the 6 week period, the control sample had attained a high peroxide value which decreased about 50% at 3 months. The peroxide value of the coated sample continued to increase over the 3 month period.

Freeze-dried sliced pork was spray-coated with a 50:50 mixture of polyglycerol ester and acetoglyceride. The coated sample exhibited a greater increase in moisture content when stored at 0° than did uncoated controls. Both coated samples and controls developed a slight yellowish color when stored 3 months at 100°F. The coating protected the color and flavor of 100°F samples against oxidation, as evaluated in rehydrated material.

Air-dried apple slices coated with a 50:50 mixture of monoglyceride and polyglycerol ester, hardened confectioner's coating butter (Wecobee HLS), and a monoglyceride/gelatin

laminate were not protected significantly against moisture pickup at 0°F. The coatings protected the flavors, color and aroma of apple slices to varying degrees. The monoglyceride/gelatin laminate became browned at 100°F. The fat coating appeared to be most effective in preserving color and flavor. The monoglyceride/polyglycerol ester coating was effective at 100°F in preserving flavor, but not at 0°F. Uncoated apple slices stored at 0°F evidenced both color and flavor deterioration after 3 months storage. Controls stored at 100°F were badly browned.

Freeze-dried pineapple slices coated with amylose laurate retained a normal color after 3 months at both 0° and 100°F. Aroma and flavor were protected to a slight extent by the acetoglyceride/soy proteinate laminate and by amylose laurate. The greatest protective effect of the coated samples, in comparison to controls, was found at 0°F.

Freeze-dried fish squares coated with a preformed ethylcellulose/acetoglyceride film retained acceptable odor and flavor after 3 months storage at 0° and 100°F. The color of the dried control and coated samples stored at 100°F was yellowish, but only the control samples were considered unacceptable following rehydration. The coating provided some moisture barrier protection in 0°F storage samples.

Shelled Brazil nuts coated with a soy proteinate/acetoglyceride laminate developed about half the peroxide value of gelatin coated nuts and controls stored at 100°F. The peroxide value remained at a low level among all samples stored at 0°.

Freeze-dried carrot slices coated with acetoglyceride /soy proteinate laminate and a three layer laminate of amylose laurate/soy proteinate/acetoglyceride were not significantly protected against oxidation at 100°F. Although coated samples retain a higher level of carotene after 3 months at 100°F than do control samples, the typical violet-like aroma of oxidized carotene is quite evident in rehydrated coated samples.

Freeze-dried peas coated with soy proteinate and with amylose myristate/soy

proteinate laminate retained better pea flavor after 3 months at 0° and 100°F than did uncoated controls. The soy proteinate coating preserved flavor to the greatest extent and this is further reflected in the higher Chlorophyll Index values for soy proteinate-coated samples.

Freeze-dried strawberries coated with polyglycerol ester-acetoglyceride mixture and polyglycerol ester-monoglyceride mixture were not protected against loss of color, flavor and aroma when stored at 100°F for 3 months. Samples stored at 0°F were acceptable after 3 months.

Rehydration of Stored Freeze Dried Foods

The rate and extent of rehydration of coated freeze-dried foods that were stored for 3 months is shown in Table 29. Comparison of uncoated storage samples with uncoated samples that had not been stored (Tables 17 and 25) indicates storage had only a slight effect on rehydration. With all samples, storage at 0°F reduced hydratability to a greater extent than did storage at 100°F.

The polyglycerol ester coating significantly reduced the hydratability of freeze-dried chicken. Polyglycerol ester and monoglycerides in a 50:50 blend reduced the hydratability of pork pieces by 20-30%. Amylose laurate reduced the rehydration of pineapple pieces by about 30% at 0° and 100°F storage temperatures. Hydratability of pineapple coated with acetoglyceride/soy proteinate laminate was somewhat lower than that of amylose laurate coated samples.

Fish squares coated with the preformed ethylcellulose-acetoglyceride film rehydrated to about the same extent as uncoated controls. It is noteworthy that this film lies entirely upon the surface of the food rather than being drawn into the food upon application as in the case of the other coated foods. The ethylcellulose-acetoglyceride film did not adversely affect rehydration as did the other coatings.

Carrots coated with acetoglyceride/soy proteinate coating hydrated to about 50% of uncoated controls stored at 0° while carrots with the amylose laurate/soy proteinate/acetoglyceride coating hydrated to about 80% of controls. Coated freeze-dried peas hydrated to about 80% of controls. Rehydrated strawberries lost piece identity and resembled a fruit puree .

No generalizations can be made regarding the effect of specific coatings on the hydratability of coated foods. The storage temperature, food product and method of coating application as well as the coating itself affect the rehydration of coated foods.

Table 1

MOISTURE VAPOR TRANSMISSION, TEMPERATURE TOLERANCE AND SOLUBILITY OF EDIBLE FILMS AND COATINGS

Composition	MVT g/sq.in /24 hrs	Temperature Tolerance -10°F	Temperature Tolerance 120°F	Water Solubility 180°F
Amylose 10% glycerol	0.797	Flexible	Brittle	Soluble
Amylose 20% glycerol	0.882	Flexible	Brittle	Soluble
Amylose 37% glycerol	1.139	Flexible	Flexible	Soluble
Amylose 50% glycerol	1.237	Flexible	Flexible	Soluble
Amylose 20% glycerol, 10% Gum Arabic	0.797	Flexible	Brittle	Soluble
Amylose 20% glycerol, 25% Gum Arabic	0.850	Flexible	Brittle	Soluble
Amylose 20% glycerol, 5% pectin	0.849	Flexible Elastic	Very Brittle	Soluble
Amylose 20% glycerol, 10% pectin	0.736	Flexible	Very Brittle	Soluble
Amylose 20% glycerol, 10% gelatin	0.795	Flexible	Very Brittle	Soluble
Amylose 20% glycerol, 25% gelatin	0.717	Flexible	Very Brittle	Soluble
Amylose 20% glycerol, 10% Wecobee HLS Fat	0.661	Flexible	Flexible	Soluble
Amylose 20% glycerol, 25% Wecobee HLS Fat	0.509	Flexible	Flexible	Soluble
Amylose in 5% monoglycerid dispersion	0.832	Flexible	Drys, Cracks	Disperses

Table 1, page 2

MOISTURE VAPOR TRANSMISSION, TEMPERATURE TOLERANCE AND SOLUBILITY OF EDIBLE FILMS AND COATINGS

Composition	MVT g/sq.in./24 hrs.	Temperature Tolerance -10°F	Temperature Tolerance 120°F	Water Solubility 180°F
Amylose 20% Glycerol, 10% Acetoglyceride	0.810	Flexible	Drys	Softens, Disperses
Amylose 20% Glycerol, 25% Acetoglyceride	0.920	Flexible	Drys	Softens, swells
Commercial Thermoplastic Starch Film (National Starch & Chem. Co.)	0.698	--	--	--
Sodium Polypectate	1.53	--	Brittle	Soluble
Sodium Polypectate 40% Gum Arabic, 30% Glycerol	1.44	--	Brittle	Soluble
Low Methoxy Pectin 20% Polyglycerol Ester	1.19	Flexible	Brittle	Soluble
Low Methoxy Pectin 20% Polyglycerol Ester 30% Glycerol	1.46	Softens, sticky	No change	Soluble
Gelatin Unplasticized	1.34	Flexible	Brittle	Soluble
Gelatin 2% Glycerol	1.09	Flexible	Brittle	Soluble
Gelatin 30% Glycerol	1.33	Flexible	Brittle	Soluble
Gelatin 2% Carbowax 6000	0.88	Flexible	Brittle	Soluble
Gelatin 10% Carbowax 6000	0.76	Flexible	Brittle	Soluble
Gelatin 10% Sodium Alginate	0.889	Flexible	Brittle	Soluble

Table 3, page 3

MOISTURE VAPOR TRANSMISSION, TEMPERATURE TOLERANCE AND SOLUBILITY OF EDIBLE FILMS AND COATINGS

Composition	MVT g/sq.in /24 hrs.	Temperature Tolerance -10°F	Temperature Tolerance 120°F	Water Solubility 180°F
Gelatin 25% Sodium Alginate	0.906	Flexible	Brittle	Soluble
Gelatin 10% Sodium Alginate 20% Polyglycerol Ester (Drewpol 6-2-0)	0.778	Flexible	Brittle	Soluble
Gelatin 10% Sodium Alginate 10% Drewpol 6-2-0 10% Carbowax 6000	0.595	Flexible	Brittle	Soluble
Gelatin 10% Sodium Hexametaphosphate	0.554	Flexible	Brittle	Soluble
Gelatin 10% Sodium Tetrame Taphosphate	0.598	Flexible	Brittle	Soluble
Gelatin 10% Sodium Tripolyphosphate	0.667	Flexible	Brittle	Soluble
Soy Flour (Kaysoy 200C) 30% Glycerol	0.40	Flexible	Flexible	Softens Swells
Isoelectric Soy Protein (D620) 30% Glycerol	0.39	Flexible	--	Softens Swells
90% Sodium Soy Proteinate (ADM) 30% Glycerol	0.48	Flexible	Brittle	Softens Swells
90% Sodium Soy Proteinate (Hercules Trate 90) 30% Glycerol	0.36	Flexible	Brittle	Softens
90% Sodium Soy Proteinate (Central Soya Promine D) 30% Glycerol	0.67	Flexible	Brittle	Softens

MOISTURE VAPOR TRANSMISSION, TEMPERATURE TOLERANCE AND SOLUBILITY OF EDIBLE FILMS AND COATINGS

Composition	MVT g/sq.in./24 hrs.	Temperature Tolerance -10°F	Temperature Tolerance 120°F	Water Solubility 180°F
Vital Wheat Gluten (Hercules) 20% Glycerol	0.79	Flexible	Flexible	Softens
Vital Wheat Gluten (Hercules) 40% Glycerol	0.85	Flexible	Flexible	Softens
Egg Albumin (Henningsen P-60)	1.07	Flexible	Brittle	Softens, Shrinks
Sodium Caseinate 25% Glycerol	0.92	Flexible	Flexible	Soluble
Sodium Caseinate 30% Polyglycerol Ester (Drewpol 3-1-5)	0.40	Flexible	Flexible	Soluble
Zein 30% Propylene Glycol	0.38	Flexible	--	Softens, Shrinks
Zein 30% Lactic Acid	0.24	Flexible	--	Softens, Shrinks
Confectioner's Coating Butter (Wecobee FW)	0.065	Brittle	Melts	Melts
Confectioner's Coating Butter (Wecobee HIS)	0.045	Brittle	Melts	Melts
Confectioner's Coating Butter (Wecobee S)	0.029	Brittle	Melts	Melts
Confectioner's Coating Butter (Wecobee S) 2% Tween 60 2% Span 60	0.066	Brittle	Melts	Melts
Glycerol Monostearate (Myverol 18-07)	0.019	Brittle	Softens	Melts, Partially Disperses
Acetylated Monoglycerides (Myvacet 5-00)	0.096	Stiff	Softens	Melts
Stearic Acid	0.141	Brittle	Softens	Melts

Stearic Acid	0.141	Brittle	Softens	Melts

Table 1, page 5

MOISTURE VAPOR TRANSMISSION, TEMPERATURE TOLERANCE AND SOLUBILITY OF EDIBLE FILMS AND COATINGS

Composition	MVT g/sq.in./24 hrs.	Temperature Tolerance -10°F	Temperature Tolerance 120°F	Water Solubility 180°F
Beeswax	0.009	Brittle	Softens	Melts Slowly
Propylene Glycol Monostearate (Glyco PGMS 64)	0.032	Brittle	Softens	Melts
Ethylcellulose Acetoglyceride 1/ Mixture	0.117-0.279	Stiff	Softens	Softens, Stretches
Amylose Laurate	0.108	Flexible	Flexible Non-tacky	Softens Ruptures
Amylose Myristate	0.067	Flexible	Softens Tacky	Softens Ruptures
Laminate Sodium Soy Proteinate/ Amylose Laurate	0.110	Flexible	Flexible	Softens Swells
Laminate Sodium Soy Proteinate/ Amylose Myristate	0.167	Flexible	Sl Flexible	Softens Swells
Laminate Ethylcellulose-Acetoglyceride/ Sodium Soy Proteinate/ Amylose Laurate	0.072	Brittle	Melts	Softens
Laminate Ethylcellulose-Acetoglyceride/ Amylose Laurate/Gelatin	0.073	Stiff Not Brittle	Softens	Softens Stretches
Laminate Ethylcellulose-Acetoglyceride/ Amylose Myristate	0.088	Brittle	Very Soft, Sticky	Softens
Laminate Ethylcellulose-Acetoglyceride/ Amylose Myristate/ Sodium Soy Proteinate	0.101	Flexible	Very Soft, Sticky	Softens, Stretches Partially Soluble

1/ See Tables 5 and 6 for detailed compositions

Table 1, page 6

MOISTURE VAPOR TRANSMISSION, TEMPERATURE TOLERANCE AND SOLUBILITY OF EDIBLE FILMS AND COATINGS

Composition	MVT g/sq.in /24 hrs	Temperature Tolerance -10°F	Temperature Tolerance 120°F	Water Solubility 180°F
Laminate Ethylcellulose-Acetoglyceride/ Amylose Laurate/ Sodium Soy Proteinate	0.081	Stiff	Soft Flexible	Softens Partially Soluble
Laminate Ethylcellulose-Acetoglyceride/ Amylose Myristate/Gelatin	0.098	Stiff Not Brittle	Brittle	Softens Stretches
Laminate Gelatin/Amylose Laurate	0.182	Sl Flexible	Stiff	Softens Partially Soluble
Laminate Gelatin/Amylose Myristate	0.266	Sl Flexible	Stiff	Softens, Partially Soluble, Sticky
Laminate Ethylcellulose-Acetoglyceride/ Gelatin	0.186			
Gelatin 5% Acetoglyceride 10% Glycerol	0.622	Flexible	Brittle	Soluble
Gelatin 5% Acetoglyceride 20% Glycerol	0.808	Flexible	Brittle	Soluble
Gelatin 10% Acetoglyceride 10% Glycerol	0.649	Flexible	Brittle	Soluble
Gelatin 10% Acetoglyceride 20% Glycerol	0.737	Flexible	Brittle	Soluble

Table 2

EFFECT OF CHEMICAL REAGENTS ON EDIBLE FILMS AND COATINGS

	Percent of Initial Weight after 24 Hours					
Coating Material	.01 M $CaCl_2$	5% NaCl	.01M pH 4	.01M pH 9.2	Oil	Water
Isoelectric Soy Protein (ADM 620) 30% Glycerol Hot Press.	114	121	114	127	104	114
Same, 15% Glycerol	125	130	126	126	104	124
Same, 30% Sorbitol	131	122	127	131	106	126
90% Sodium Proteinate (ADM) Hot Press 30% Glycerol	121	142	106	324	102	240
90% Sodium Proteinate (Hercules) Hot Press 30% Glycerol	117	148	116	311	106	190
90% Sodium Proteinate (Central Soya Promine D) 30% Glycerol Hot Press	128	155	127	410	108	270
Sodium Caseinate Cast from 50% ETOH Dispersion	Soluble	Soluble	Soluble	Soluble	No Change	Soluble
Albumin (Henningsen P-60) Hot Press	110	103	100	139	101	110
Gluten (Hercules) Hot Press 19% Glycerol	158	154	148	173	100	150
Zein, Cast from Propylene Glycol	130	162	194	314	106	275
Gelatin Type A 250 Bloom Cast Film	Soluble	Soluble	Soluble	Soluble	No Change	Soluble
Soy Flour 50% Protein Hot Press 30% Glycerol	117	142	123	243	104	180

Table 2, cont'd Effect of Chemical Reagents on Edible Films and Coatings

Coating	Percent of Initial Weight after 24 Hours					
	.01M $CaCl_2$	5% NaCl	pH 4	pH 9.2	Oil	Water
Gelatin	996	Soluble	Soluble	1400	114	Soluble
Soy Proteinate 20% Glycerol	1020	Soluble	640	Soluble	980	Soluble
Polyglycerol Ester Drewpol 3-1-S	206	220	292	345	107	-
Amylose Laurate	103	104	105	124	250	102
Amylose Myristate	118	159	153	115	Soluble	107
Ethylcellulose-Acetoglyceride	178	172	196	206	150	228
Acetoglyceride/ Soy Proteinate	206	160	Disintegrates	148	141	135
Amylose Myristate/ Soy Proteinate	322	455	339	739	358	
Gelatin Monoglyceride	Disintegrates	Disintegrates	Disintegrates	Disintegrates	Monoglyceride Soluble	Disintegre
Acetoglyceride Polyglycerol Ester (3-1-S)	149	157	176	620	107	351
Monoglyceride Polyglycerol Ester (3-1-S)	167	172	174	510	103	235
Monoglyceride Polyglycerol Ester (6-2-S)	204	187	230	585 Weak	146	450
Acetoglyceride Polyglycerol Ester (6-2-S)	141	166	172	217	113	905
Amylose Laurate/ Soy Proteinate/ Acetoglyceride	118	158	161	112	105	135

Acetoglyceride

Table 3

OXYGEN PERMEABILITY AND PHYSICAL CHARACTERISTICS OF EDIBLE FILMS

Film	Oxygen Permeability: Time Hours	Oxygen Permeability: % O_2 in Test Cell	Oxygen Permeability: Permeability cc mils / day m^2 atm	Tensile Strength PSI	% Elongation	Tear Stre: lbs/inch
Gelatin Type A 250 Bloom, Unplasticized	238	2.5	113	17,000 0.75-0.9 mils	36	180
Same 10% Glycerol	--	--	--	10,500 1.3 mils	102	344
Same 30% Glycerol	--	--	--	2,270 1.9 mils	15	413
Same 10% Carbowax 6000	--	--	--	5,253 1.8 mils	2	146
Same, 10% Mono-pentaerythritol	238	76.4	10,100	10,800 1.4 mils	2	111
Soy Flour (50% Protein) Hot Press, 30% Glycerol	152.9	3.5	2,320	1,433 8.3 mils	40	123
Isoelectric 90% Soy Protein (ADM) Hot Press 30% Glycerol	56.5	23.6	28,400	2,270 12 mils	33	--
90% Soy Proteinate (ADM) Hot Press, 30% Glycerol	164.5	5.7	1,200	1,780 3.4 mils	17	299
90% Soy Proteinate (Central Soya Promine D) Hot Press, 30% Glycerol	78.1	1.6	2,370	1,930 5 mils	58	261
Acetoglyceride/soy Proteinate Laminate	24 112	3.0 9.1	-- --	128 7 mils	41	70
Amylose Laurate/ Soy Proteinate/ Acetoglyceride Laminate	24 112	2.9 8.5	-- --	1,220 2.5 mils	19	615

Table 3, page 2 OXYGEN PERMEABILITY AND PHYSICAL CHARACTERISTICS OF EDIBLE FILMS

Film	Oxygen Permeability			Tensile Strength PSI	% Elongation	Tear Stren lbs/inch
	Time Hours	% O_2 in Test Cell	Permeability cc mils / day m^2 atm			
Extruded Amylose (American Maize) ARD 1480	58	24.1	7,260	--	--	--
Myverol 18-07 Monoglyceride	52.5	90.1	1.68×10^6	--	--	--
Myvacet 5-00 Acetoglyceride	382	34.9	34,000	--	--	--
Beeswax	64	71.2	9.29×10^5	--	--	--
Amylose-Gelatin	292	23.9	5,500	--	--	--
Ethylcellulose-Acetoglyceride/	24	9.7	--	--	--	--
Amylose Laurate	112	28	--	--	--	--
Ethylcellulose-Acetoglyceride/	24	5.3	--	--	--	--
Amylose Laurate/ Soy Proteinate	48	8.1				
Gluten (Hercules) Hot Press, 20% Glycerol	56.3	26.4	23,800	1,360 8 mils	163	263
Sodium Caseinate Cast from 50% ETOH	100 (13% Glycerol)	27.4	5,716	227 (25% Glycerol)	68	49
Albumin (Henningsen P-60) Hot Press	--	--	--	2,060	100	247
Zein Cast from 70% Isopropanol 30% Propylene Glycol	149.8	5.0	789	5,780 1.0 mil	2.7	178
Amylose Laurate	--	--	--	441 1.5 mils	9	--
Amylose Myristate	--	--	--	488	9	--

Table 3, page 3

OXYGEN PERMEABILITY AND PHYSICAL CHARACTERISTICS OF EDIBLE FILMS

Film	Oxygen Permeability: Time Hours	Oxygen Permeability: % O_2 in Test Cell	Permeability cc mils / day m^2 atm	Tensile Strength PSI	% Elongation	Tear Stre[ngth] lbs/inch
Ethylcellulose-Acetoglyceride	89 (51D Table 6) 262 (51E Table 6)	22.4 75.7	15,600 38,200	683 5.5 mils	385	79
Amylose Myristate/Soy Proteinate Laminate	24 119	0.7 2.1		7,685 2.5 mils	2	2860
Gelatin/Monoglyceride Laminate	--	--	--	660 5 mils	59.6	395

Table 4

CHARACTERISTICS OF ETHYLCELLULOSE-ACETOGLYCERIDE COATINGS

Coating	MVT g/sq in/24 hrs	Temperature Tolerance Freezer	120°F	180°F Water
26-1	0.215 0.245	flexible	sl soft	softens
26-2	0.117 0.142	sl brittle	softens	softens, melts
27-2	0.182 0.151	sl brittle	softens becomes sticky	softens melts
27-3	0.203 0.203	sl brittle	sticky	melts
27-4	0.186 0.187	sl brittle	soft	melts
27-5	0.119 0.157	sl brittle	soft	melts
27-8	0.122 0.148	sl brittle	soft	melts
33-3	0.144 0.157	sl brittle	very soft	melts
34-1	0.200 0.279	sl brittle	very soft	melts
34-2	0.205 0.214	sl brittle	very soft	melts
34-3	0.163 0.176	sl brittle	very soft	melts
55-4	0.151 0.194	flexible	soft	very soft

Table 5

COMPOSITION OF ETHYLCELLULOSE-ACETOGLYCERIDE COATINGS

	26-1	26-2	27-3	27-2	27-5	27-4	27-8	55-4	33-3	34-1	34-2	34-3
Ethocell	27.96	29.41	29.4	29.4	26.4	26.4	26.4	15.15	17.24	17.24	17.24	17.24
Myvacet 5-00[1]	11.18	11.76	29.4	58.8	10.6	10.6	52.8	30.30	68.94	68.94	68.94	68.94
Wecobee HLS[2]	44.74	47.1	29.4	-	42.2	42.2	-	30.30	-	-	-	-
6-2-S[3]	-	5.88	5.9	5.9	21.2	10.6	21.2	-	6.89	6.89	6.89	6.89
6-2-O[3]	-	5.88	5.9	5.9	-	10.6	-	-	6.89	6.89	6.89	6.89
10-1-S[3]	-	-	-	-	-	-	-	24.25	-	-	-	-
Glycerol	16.10											
Propylene Glycol Alginate									.04			
Carageenan										.04		
Guar Gum											.04	
Ammonium Calcium Alginate												.04

1. Acetylated Monoglyceride - Distillation Products Industries
2. Confectioners Coating Butter - Drew Chemical Corporation
3. Polyglycerol - Fatty Acid Esters - Drew Chemical Corporation

Table 6

EFFECT OF ETHYLCELLULOSE GRADE ON CHARACTERISTICS OF ETHYLCELLULOSE--ACETOGLYCERIDE COATINGS

Coating No	Ethoxy Range %	Viscosity cps	MVT g/sq in/24 hrs	Temperature Tolerance		
				Freezer	120°F	180°F Water
51A	45.0-46.5	20	0.168 0.191	flexible	stable	slight softening
51B	45.0-46.5	50	0.177 0.178	flexible	stable	no softening
51D	45.0-46.5	100	0.182 0.193	flexible	stable	no softening
51E	48.0-49.5	20	0.234 0.248	flexible	softens	softens
51F	48.0-49.5	50	0.175 0.178	flexible	softens	softens stretches
51C	48.0-49.5	100	0.165 0.165	flexible	softens	softens

Composition:	Ethylcellulose	29.4%	Dow Chemical Company
	Myvacet 5-00	58.8	Distillation Products Industries
	Drewpol 6-2-S	5.9	Drew Chemical Corporation
	Drewpol 6-2-0	5.9	Drew Chemical Corporation

Table 7

EFFECT OF COATINGS ON FRAGMENTATION OF GRAHAM CRACKERS

Coating	% Applied	Method of Application	Fragmentation % - USBS #4 Sieve
None	--	--	27-30
Acetylated Monoglyceride	15.5	Spray	17.5
Polyglycerol Ester Drewpol 3-1-S	17	Spray	19.3
Emulsion: Stearic Acid, Polyglycerol Ester	16	Spray	30
Emulsion: Carbowax 6000, Polyglycerol Ester, Hardened Fat	9.4	Spray	25
Gum Arabic + Ammonium Calcium Alginate	7	Spray	43
Edible Shellac	6	Spray	36
Ethylcellulose-Acetoglyceride	17	Preformed film	6
Ethylcellulose-Acetoglyceride	18	Brushed on hot melt	9

Table 8

EFFECT OF COATINGS ON FRAGMENTATION OF FREEZE-DRIED FOODS

		Fragmentation at 20-30°F				Fragmentation at 80-90°F			
				No. Pieces				No. Pieces	
Food	Coating	%+USBS#4	%-USBS#8	Initial	Final	%+USBS#4	%-USBS#8	Initial	Final
Freeze-Dried Sliced Pork	Polyglycerol Ester + Acetoglyceride	93.2	2.9	9	18	83.9	5.6	9	43*
	None	87.5	4.4	8	21	89.8	2.9	5	17
Freeze-Dried Diced Chicken	Monoglyceride + Polyglycerol Ester	84.8	8.8	13	22	84	10.8	14	22
	None	76.2	18.8	15	28*	64.4	27.3	13	27*
Freeze-Dried Fish Sticks	Ethylcellulose + Acetoglyceride	100	0	6	6	100	0	6	6
	None	90.7	8	8	20	91.2	7.9	8	21
Freeze-Dried Scrambled Eggs	Ethylcellulose + Acetoglyceride	99.7	Negligible	6	6	99.6	Negligible	6	6
	None	79.5	14.1	4	>100	67.4	21.2	6	>100
Freeze-Dried Strawberries	Polyglycerol Ester + Acetoglyceride	88.2	8.2	50	50	67.3	27.1	50	50
	None	65.9	27.6	50	50	62.1	30.0	32	32
Fruitcake Squares	Ethylcellulose + Acetoglyceride	100	0	4	4	100	0	4	4
	None	99.4	Negligible	3	3	99.1	Negligible	3	3

* Plus many smaller uncounted crumbs.

Table 9

REHYDRATION OF FREEZE-DRIED FOODS
COATED TO RESIST FRAGMENTATION

Food	Coating	7% Coating	Water Absorption % of Dry Weight			Rate of Rehydration g Water/100 g Dry Product/Min	
			5 min	10 min	15 min	5 min	15 min
Sliced Pork	Polyglycerol Ester + Acetoglyceride	10.9	33.7	33.7	35.0	6.7	2.4
	None	--	64.3	74.8	79.7	12.8	5.3
Diced Chicken	Monoglyceride + Polyglycerol Ester	11.4	130.2	133.2	134.1	26.0	8.9
	None	--	106.3	117.4	119.7	21.3	7.24
Fish Sticks	Ethylcellulose + Acetoglyceride	21.3	212.2	212.7	222.4	42.4	14.8
	None	--	248.8	261.9	260.3	49.8	17.3
Scrambled Eggs	Ethylcellulose + Acetoglyceride	16.1	91.9	162.3	172.6	18.4	11.5
	None	--	186.9	222.6	242.7	37.4	16.1
Strawberries	Polyglycerol Ester + Acetoglyceride	35.4	166.7	159.6	--	33.4	11.3 (10 min)
	None	--	367.2	336.5	--	73.4	22.4 (10 min)

Table 10

MOISTURE VAPOR TRANSMISSION OF FILMS AT 20-30°F AND 80-90°F

Film	20-30°F[1] Thickness mils	20-30°F[1] M.V.T. g/sq.in/24 hrs	80-90°F[2] Thickness mils	80-90°F[2] M.V.T. g/sq.in/24 hrs
Amylose Laurate	4	0.0659	3 3	0.029 0.084
Acetoglyceride (Myvacet 5-00)	21.5	0.0025	20 20	0.109 0.126
Polyglycerol Ester (Drewpol 3-1-S)	40.5 36.0	0.021 0.023	31.0 31.5	0.095 0.099
Hardened Fat (Wecobee HLS)	23.5	0.025	22.0 22.0	0.131 0.124
Monoglyceride Polyglycerol Ester Mixture (Myvorol 18-07 + Drewpol 6-2-S)	28.5 31.0	0.003 0.001	36.0 38.0	0.071 0.084
Ethylcellulose Acetoglyceride Mixture	8 7.5	0.005 0.006	8.5 12.5	0.065 0.051
Soy Proteinate/ Acetoglyceride Laminate	8 5	0.0005 0.034	9 8	0.029 0.029
Acetoglyceride/ Soy Proteinate Laminate	17.5 15.0	0.008 0.004	6.5 27.0	0.152 0.049
Monoglyceride/ Gelatin Laminate	6.0 6.0	0.058 0.056	13 16	0.145 0.199
Amylose Myristate/ Soy Proteinate Laminate	2.5 2.5	0.095 0.095	3 3	1.023 1.045
Amylose Laurate/Soy Proteinate/Acetoglyceride Laminate	14.5 13.5	0.003 0.004	9.0 8.5	0.066 0.072

1. 100 % RH
2. 82 % RH

2. 82 % RH

Table 11

STORAGE OF FOODS COATED TO PREVENT THE EFFECT OF MOISTURE

Conditions: 2 weeks; 70°F; 80-90% RH

Food	Coating	% Coating	% Moisture Initial	% Moisture Final	% Weight Increase
Freeze-Dried Diced Chicken	Polyglycerol Ester (Drewpol 3-1-S)	16.0	0.9	9.93	11.0
	None	--	2.6	9.4	12.5
Air-Dried Sliced Apples	Monoglyceride Polyglycerol Ester Mixture	17.0	1.4	18.1	16.3
	Hard Confectioner's Butter	11.3	2.1	9.6	16.0
	None	--	3.2	22.1	21.4
Freeze-Dried Sliced Pineapple	Amylose Laurate	12.0	2.8	13.9	23.6
	None	--	4.4	16.3	25.6
Graham Crackers	Ethylcellulose-Acetoglyceride Mixture	19.3	1.4	10.5	10.9
	Acetoglyceride	20.1	1.4	8.2	9.5
	None	--	1.5	12.8	17.5

Table 12

REHYDRATION OF FOODS COATED TO RFSIST MOISTURE

Food	Coating	% Coating Applied	Water Absorption Percent of Dry Weight 5 Min	10 Min	15 Min	Rate of Rehydration 6 water/100 g dry product/min 5 Min	15 Min
Freeze-Dried Chicken	Polyglycerol Ester (Drewpol 3-1-S)	12.8	130	133	133	26	8.9
	None	--	106	117	120	21.2	8
Air-Dried Apple Slices	Monoglyceride-Polyglycerol Ester Mixture	19.4	69	106	133	13.8	8.9
	Confectioner's Fat (Wecobee HLS)	11.5	89	125	157	17.8	10.5
	None	--	94	139	169	18.8	11.3
Freeze-Dried Sliced Pineapple	Amylose Laurate	7.8	143	183	205	28.6	13.7
	None	--	161	195	214	32.2	14.3

Table 13

OXYGEN PERMEABILITY OF UNPLASTICIZED GELATIN FILM

Temperature-Humidity Condition	Time Hours	% O_2 in Test Cell	Permeability $\frac{\text{cc mils}}{\text{day } m^2 \text{ atm.}}$
80-90°F $<$ 20% RH	44.6	94.6	0.323×10^6
80-90°F $>$ 70% RH	78.5	2.1	281
20-30°F $<$ 20% RH	44.1	1.2	552
20-30°F $>$ 70% RH	49.6	7.5	1,850

Table 14

OXYGEN PERMEABILITY OF SODIUM SOY PROTEINATE FILM

Temperature-Humidity Condition	Time Hours	% O_2 in Test Cell	Permeability $\frac{\text{cc mils}}{\text{day m}^2\text{ atm.}}$
80-90°F $<$ 20% RH	44.6	86.9	0.322×10^6
80-90°F $>$ 70% RH	78.6	65.7	35,900
20-30°F $<$ 20% RH	44.2	93.6	715,000
20-30°F $>$ 70% RH	49.7	89.1	283,000

Table 15

OXYGEN PERMEABILITY OF ACETOGLYCERIDE-
SODIUM SOY PROTEINATE LAMINATED FILM

Temperature-Humidity Condition	Time Hours	% O_2 in Test Cell	Permeability $\frac{\text{cc mils}}{\text{day } m^2 \text{ atm.}}$
80-90°F $<$ 20% RH	44.3	95.1	44.2×10^6
80-90°F $>$ 70% RH	78.4	4.2	1,710
20-30°F $<$ 20% RH	44.1	48.7	89,100
20-30°F $>$ 70% RH	49.5	97.3	2.56×10^6

Table 16

STORAGE OF FOODS COATED TO PREVENT OXIDATION

Food	Initial Level of Oxidation	Coating	Level of Oxidation after One Month — Storage Conditions: 20-30°F $<$20%RH	20-30°F $>$70%RH	80-90°F $<$20%RH	80-90°F $>$70%RH
Freeze-Dried Carrots	264 mg. Carotene/lb	Acetoglyceride-Sodium Soy Proteinate	142.5 mg/lb	119 mg/lb	39.6 mg/lb	99.6 mg/lb
		None	138 mg/lb	45 mg/lb	38.4 mg/lb	270 mg/lb
Shelled Brazil Nuts	0.7 meq. peroxide/lb	Gelatin (Unplasticized)	14.3 meq/lb	14.3 meq/lb	2.1 meq/lb	2.7 meq/lb (1 wk, moldy)
		None	8.8 meq/lb	1.8 meq/lb	1.1 meq/lb	43.8 meq/lb
Compressed Potato Chip Bar	2.2 meq peroxide/lb	Sodium Soy Proteinate	12.6 meq/lb (cracked coating)	4.0 meq/lb	3.5 meq/lb	1.3 meq/lb (2 wks, moldy
		None	6.4 meq/lb	7.5 meq/lb	13.8 meq/lb	1.3 meq/lb (2 wks, moldy
Freeze-Dried Peas	4.13 chlorophyll index	Sodium Soy Proteinate	3.71	3.01	3.26	2.40
		None	3.88	3.72	3.84	3.75
Compressed Ground Corn Bar	0.2 meq peroxide/lb	Sodium Soy Proteinate	1.0 meq/lb	7.7 meq/lb	1.6 meq/lb	None (2 weeks, sl moldy)
		None	6.3 meq/lb	0.6 meq/lb	10.9 meq/lb	18.2 meq/lb (2 weeks)

Table 17

REHYDRATION OF FREEZE-DRIED FOODS COATED TO RESIST OXYGEN

Food	Coating	% Coating	Water Absorption Percent of Dry Weight			Rate of Rehydration g water/100 g dry product/min	
			5 Min	10 Min	15 Min	5 min	15 min
Freeze-Dried Carrot Slices	Acetoglyceride-Sodium Soy Proteinate	--	131	165	190 284 30 min	26.3	12.7
	None	--	412	478	510	82.5	34
Freeze-Dried Peas	Sodium Soy Proteinate	--	284	296	304	56.8	20.2
	None	--	284	309	324	56.8	21.6

Table 18

OXYGEN PERMEABILITY OF A GELATIN-MONOGLYCERIDE LAMINATED FILM

Temperature-Humidity Conditions	Time Hours	% O_2 in Test Cell	Permeability $\frac{\text{cc mils}}{\text{day m}^2\text{ atm.}}$
80-90°F $<$ 20% RH	48 72.6	0.47 0.56	209 165
80-90°F $>$ 70% RH	78.5	1.8	397
20-30°F $<$ 20% RH	44.2	45.6	63,400
20-30°F $>$ 70% RH	49.7	80.6	311,000

Table 19

OXYGEN PERMEABILITY AMYLOSE LAURATE-SODIUM SOY PROTEINATE-ACETOGLYCERIDE LAMINATED FILM

Temperature-Humidity Conditions	Time Hours	% O_2 in Test Cell	Permeability $\frac{\text{cc mils}}{\text{day } m^2 \text{ atm.}}$
80-90°F 20% RH	48 72.5	0.92 1.6	633 734
80-90°F 70% RH	78.4	5.6	2,480
20-30°F 20% RH	44	97.3 Cracked	3,610,000
20-30°F 70% RH	49.4	0.81	549

Table 20

OXYGEN PERMEABILITY OF AMYLOSE MYRISTATE-SODIUM SOY PROTEINATE LAMINATED FILM

Temperature-Humidity Conditions	Time Hours	% O_2 in Test Cell	Permeability $\frac{cc\ mils}{day\ m^2\ atm.}$
80-90°F $<$ 20% RH	44.4	94.6	571,000
80-90°F $>$ 70% RH	78.4	3.7	807
20-30°F $<$ 20% RH	44.0	95.2	1,720,000
20-30°F $>$ 70% RH	49.4	94.8	479,000

Table 21

STORAGE OF FOODS COATED TO PREVENT
THE EFFECTS OF MOISTURE AND OXYGEN

Conditions: 1 month; 80-90°F; > 70% RH

Food	Coating	Percent Moisture Initial	Percent Moisture Final	Percent Weight Gain	Oxidation Initial	Oxidation Final	
Freeze-Dried Diced Chicken	Amylose Myristate/Soy Protein Laminate	2.2	12.0	13.85	2.7 meq peroxide/lb	14.7 meq peroxide/lb	
	None	2.58	13.1	13.5	<0.1 meq peroxide/lb	13.8 meq peroxide/lb	
Freeze-Dried Sliced Pineapple	Acetoglyceride/Soy Proteinate Laminate	4.24	12.2	21.7	--	--	mold growth
	None	4.44	15.6	20.5	--	--	mold growth
Freeze-Dried Sliced Carrots	Amylose Laurate/Soy Proteinate/ Acetoglyceride Laminate	3.79	22.9	18.1	177 mg Carotene/lb	140 mg Carotene/lb	mold growth
	None	2.62		26.6	264 mg Carotene/lb	10.3 mg Carotene/lb	mold growth
Shelled Brazil Nuts	Soy Proteinate/Acetoglyceride Laminate	1.1	3.27	4.23	4.9 meq peroxide/lb	31.9 meq peroxide/lb	mold growth
	None	1.42	3.53	4.75	9.0 meq peroxide/lb	43.8 meq peroxide/lb	mold growth
Freezed-Dried Sliced Apples	Monoglyceride/Gelatin Laminate		13.8	17.0	--	--	mold growth browned
	None	3.22	21.0	39.6	--	--	mold growth browned
Freeze-Dried Peas	Amylose Myristate/Soy Proteinate Laminate	2.58	21.3	17.2	3.10 Chlorophyll Index	1.87 Chlorophyll Index	mold growth
	None	2.01	24.3	20.6	3.28 Chlorophyll Index	1.94 Chlorophyll Index	mold growth

Table 22

STORAGE OF FOODS COATED TO
PREVENT THE EFFECTS OF MOISTURE AND OXYGEN

Conditions: 1 month; 80-90°F, <20% RH

Food	Coating	Percent Moisture Initial	Percent Moisture Final	Percent Weight Gain	Oxidation Initial	Oxidation Final	Remarks
Freeze-Dried Diced Chicken	Amylose Myristate/Soy Protein Laminate	0.6	1.2	1.2	2.7 meq Peroxide/lb	33.3 meq Peroxide/lb	
	None	2.1	1.1	0.8	6.6 meq Peroxide/lb	8.3 meq Peroxide/lb	
Freeze-Dried Sliced Pineapple	Acetoglyceride/Soy Protein Laminate	4.2	2.0	0.5	--	--	
	None	4.4	2.8	2.2	--	--	
Freeze-Dried Sliced Carrots	Amylose Laurate/Soy Proteinate/Acetoglyceride Laminate	2.9	2.0	4.3	177 mg Carotene/lb	48.7 mg Carotene/lb	Good color
	None	2.6	1.9	0.1	264 mg Carotene/lb	38.4 mg Carotene/lb	Color very faded
Shelled Brazil Nuts	Soy Proteinate/Acetoglyceride Laminate	1.0	0.6	1.7	4.9 meq Peroxide/lb	8.0 meq Peroxide/lb	
	None	1.42	3.1	1.25	9.0 meq Peroxide/lb	1.1 meq Peroxide/lb	
Air-Dried Sliced Apples	Monoglyceride/Gelatin Laminate		4.4	4.3	--	--	
	None	3.2	1.95	0.7	--	--	
Freeze-Dried Peas	Amylose Myristate/Soy Proteinate Laminate	2.5	1.0	0.8	3.10 Chlorophyll Index	2.50 Chlorophyll Index	Discolored
	None	2.0	1.4	2.4 (gain)	3.28 Chlorophyll Index	3.84 Chlorophyll Index	Color faded

Table 23

STORAGE OF FOODS COATED TO PREVENT THE EFFECTS OF MOISTURE AND OXYGEN

Conditions: 1 month; 20-30°F; >70% RH

Food	Coating	Percent Moisture Initial	Percent Moisture Final	Percent Weight Gain	Oxidation Initial	Oxidation Final	
Freeze-Dried Diced Chicken	Amylose Myristate/ Soy Proteinate	2.2	3.68	4.46	2.7	23.6	
	None	2.58	9.32	6.62	6.1	6.53	
Freeze-Dried Sliced Pineapple	Acetoglyceride/ Soy Proteinate Laminate	4.24	7.93	0.85	-	-	Sl Sticky
	None	4.44	3.75	9.4	-	-	
Freeze-Dried Sliced Carrots	Amylose Laurate/ Soy Proteinate/ Acetoglyceride Laminate	3.79	6.84	2.48	177 mg Carotene/lb	101.4 mg Carotene/lb	
	None	2.62	10.1	6.47	264 mg Carotene/lb	45 mg Carotene/lb	
Shelled Brazil Nuts	Soy Proteinate/ Acetoglyceride Laminate	1.1	2.74	0.34	4.9 meq peroxide/lb	2.1 meq peroxide/lb	
	None	1.42	2.12	0.42	9.0 meq peroxide/lb	1.8 meq peroxide/lb	
[illegible]d Apple Slices	Monoglyceride/ Gelatin Laminate	14.2	2.87	3.68 % wt loss	-	-	
	None	3.22	8.37	3.42	-	-	
Freeze-Dried Pease	Amylose Myristate/ Soy Proteinate Laminate	2.58	6.89	3.46	3.10 Chlorophyll Index	3.27 Chlorophyll Index	
	None	2.01	4.74	6.13	3.28 Chlorophyll Index	3.72 Chlorophyll Index	

Table 24

STORAGE OF FOODS COATED TO PREVENT
THE EFFECTS OF MOISTURE AND OXYGEN

Conditions: 1 month; 20-30°F; $\angle$ 20% RH

Food	Coating	Percent Moisture Initial	Percent Moisture Final	Percent Weight Gain	Oxidation Initial	Oxidation Final
Freeze-Dried Diced Chicken	Amylose Myristate/Soy Proteinate Laminate	2.2	2.2	-2.96	6.6 meq. Peroxide/lb	6.89 meq. Peroxide/lb
	None	2.58	2.15	-0.33	6.1 meq Peroxide/lb	2.1 meq Peroxide/lb
Freeze-Dried Sliced Pineapple	Acetoglyceride/Soy Proteinate Laminate	4.24	3.32	-0.50	--	--
	None	4.44	6.42	-0.77	--	--
Freeze-Dried Sliced Carrots	Amylose Laurate/Soy Proteinate/ Acetoglyceride Laminate	3.79	3.05	-1.66	219 mg Carotene/lb	129.5 mg Carotene/lb
	None	2.62	1.70	-0.41	264 mg Carotene/lb	138 mg Carotene/lb
Shelled Brazil Nuts	Soy Proteinate/ Acetoglyceride Laminate	1.1	2.24	-0.26	4.9 meq Peroxide/lb	7.0 meq Peroxide/lb
	None	1.42	0.50	-0.32	9.0 meq Peroxide/lb	8.8 meq Peroxide/lb
Air-Dried Sliced Apples	Monoglyceride/Gelatin Laminate	14.2	10.5	-4.76	--	--
	None	3.22	2.47	-0.20	--	--
Freeze-Dried Peas	Amylose Myristate/Soy Proteinate Laminate	2.58	2.87	-1.32	3.10 Chlorophyll Index	3.13 Chlorophyll Index
	None	2.01	1.54	No Change	3.28 Chlorophyll Index	3.88 Chlorophyll Index

Table 25

REHYDRATION OF FREEZE-DRIED FOODS COATED TO RESIST THE EFFECTS OF MOISTURE AND OXYGEN

Food	Coating	% Coating	Water Absorption Percent of Dry Weight			Rate of Rehydration g water/100g dry prod/min	
			5 min	10 min	20 min	5 min	20 min
Diced Chicken	Amylose Myristate/ Soy Proteinate	9.1	114	118	129	22.8	6.4
	None	--	106	117	118	21.2	5.9
Sliced Pineapple	Acetoglyceride/ Soy Proteinate	26.2	48	79	126	9.6	6.3
	None	--	161	195	224	32.2	11.2
Sliced Carrots	Amylose Laurate/ Soy Proteinate/ Acetoglyceride	16.8	170	225	274	34	13.7
	None	--	413	480	530	82.5	26.5
Air-Dried Apple Slices	Monoglyceride/ Gelatin	18.3	34.5	59.5	154	6.9	7.7
	None	--	94	139	195	18.8	9.8
Peas	Amylose Myristate/ Soy Proteinate	14.5	198	257	300	39.6	15
	None	--	284	308	331	56.8	16.5

Table 26

PRESERVATIVE COATINGS TO PREVENT GROWTH OF MICROORGANISMS

Food	Coating and Preservative	Microbial Growth — Days Storage Time: 3	5	6	7	8	9	12	13	14	15	18
Sliced Salami	Uncoated				-	+	++++	++++				
	Coated-No Preservative				+	++	++++	++++				
	Potassium Sorbate				-	-	-	-				
	Methyl:Propyl Parabens				-	-	-	-				
Gouda Cheese	Uncoated		++	++++								
	Coated-No Preservative		++++	++++								
	Potassium Sorbate		-	-								
	Methyl:Propyl Parabens		-	++								
White Bread Bars	Uncoated	+		++++	++++							
	Coated-No Preservative	+		+	++							
	Propyl Paraben	+		+	++							
	Methyl Paraben	-		+	+							
	Potassium Sorbate	-		+	+							
Date Bars	Uncoated								++++	++++	++++	++++
	Coated-No Preservative								++	++	++	+++
	Propyl Paraben								-	-	-	-
	Sorbic Acid								-	-	-	-

TABLE 27

THREE-MONTH STORAGE STUDY OF COATED FOODS

Food	Temperature	Coating	6 Week Evaluation % Moisture	6 Week Evaluation % Wt Change	6 Week Evaluation Remarks	3 Month Evaluation % Moisture	3 Month Evaluation % Wt Change	3 Month Evaluation Remarks
Fruit Cake	0°	Ethylcellulose-Acetoglyceride	6.8	0.1	No Change	6.8	No Change	
	100°	Ethylcellulose-Acetoglyceride	2.0	-13.2	Hard, dark color	4.0	-13.4	Sl dark color
	0°	None	5.9	- 0.8		6.7	- 0.4	
	100°	None	0.2	0.8		3.6	0.4	Hard, yellow color
Freeze-Dried Chicken	0°	Polyglycerol Ester	2.6	4.0		10.6	7.3	
	100°	Polyglycerol Ester	2.9	1.4		2.9	2.4	Sl dark
	0°	Amylose Myristate/ Soy Proteinate	6.8	4.2	4.6 Meq Peroxide/lb	10.6	6.9	6.7 meq peroxide/lb Sl dark
	100°	Amylose Myristate/ Soy Proteinate	2.6	- 0.4	47.6 Meq Peroxide/lb	3.6	- 8.4	30.0 meq peroxide/lb Sl dark
	0°	Polyglycerol Ester + Monoglyceride	3.4	7.3		11.6	9.5	
	100°	Polyglycerol Ester + Monoglyceride	1.7	1.2	6.4 Meq	3.2	1.8	
	0°	None	4.4	7.8	2.2 Meq Peroxide/lb	7.3	10.7	16.6 meq peroxide/lb
	100°	None	2.1	- 1.2	13.9 Meq Peroxide/lb	2.0	- 1.7	Set yellow
Graham Crackers	0°	Acetoglyceride	2.6	2.0		5.5	7.0	
	100°	Acetoglyceride	0.66	- 0.5		2.8	0.5	
	0°	Ethylcellulose-Acetoglyceride	2.7	1.5		5.3	2.3	
	100°	Ethylcellulose-Acetoglyceride	1.70	- 0.5		2.6	0.5	
	0°	None	4.6	4.2		5.4	5.1	
	100°	None	0.1	- 0.6		1.3	- 0.6	

Table 27, page 2
(Continued)

THREE-MONTH STORAGE STUDY OF COATED FOODS

Food	Temperature °F	Coating	6 Week Evaluation % Moisture	6 Week Evaluation % Wt Change	6 Week Evaluation Remarks	3 Month Evaluation % Moisture	3 Month Evaluation % Wt Change	3 Month Evaluation Remarks
Freeze-Dried Scrambled Egg Bar	0°	Ethylcellulose-Acetoglyceride	2.8	2.0		6.1	3.1	
	100°	Ethylcellulose Acetoglyceride	2.2	1.5		4.9	3.9	
	0°	None	9.5	8.9		8.8	11.2	
	100°	None	1.1	1.3		5.1	1.3	Color faded
Compressed Corn Bar	0°	Soy Proteinate	3.8	0.3	1.0 Meq peroxide/lb	11.9	0.5	4.0 meq peroxide/lb Color badly faded
	100°	Soy Proteinate	3.1	-10.2	No peroxide Oxygen	2.5	- 8.4	1.8 meq peroxide/lb Color badly faded
	0°	None	9.9	- 0.2	2.5 Meq peroxide/lb	8.4	- 0.4	16.9 meq peroxide/lb
	100°	None	1.0	-13.9	12.5 Meq peroxide/lb	3.8	-13.6	11.7 meq peroxide/lb Color faded
Compressed Potato Chip Bar	0°	Soy Proteinate	3.9	No Change	3.9 Meq peroxide/lb	5.2	No Change	4.2 meq peroxide/lb Film cracks
	100°	Soy Proteinate	2.3	-13.7	7.0 Meq peroxide/lb	2.4	-13.[illegible]	29.0 meq peroxide/lb Coating intact
	0°	None	1.3	1.8	3.3 Meq peroxide/lb	2.4	[illegible].3	6.2 meq peroxide/lb
	100°	None	0.9	- 3.3	32.5 Meq peroxide/lb	0.8	- 3.1	18.4 meq peroxide/lb
Freeze-Dried Sliced Pork	0°	Polyglycerol Ester + Acetoglyceride	5.2	6.3		10.7	8.2	
	100°	Polyglycerol Ester + Acetoglyceride	-	0.7		3.8	1.1	Yellowish color
	0°	None	3.2	4.2		6.4	7.0	
	100°	None	0.1	2.0		2.0	1.8	Slightly yellow

Table 27, page 3
(Continued)

THREE-MONTH STORAGE STUDY OF COATED FOODS

Food	Temperature °F	Coating	6 Week Evaluation % Moisture	% Wt Change	Remarks	3 Month Evaluation % Moisture	% Wt Change	Remarks
Air-Dried Sliced Apples	0°	Monoglycerides Polyglycol Ester	3.2	1.7		7.6	3.0	
	100°	Monoglycerides Polyglycerol Ester	2.3	- 0.2		4.4	0.7	
	0°	Confectioners Coating Butter	3.4	0.6		8.9	2.4	
	100°	Confectioners Coating Butter	2.2	- 0.3		5.9	1.0	
	0°	Monoglyceride/ Gelatin Laminate	6.4	1.2		10.3	2.8	Good color
	100°	Monoglyceride/ Gelatin Laminate	2.9	- 6.0		5.2	- 5.7	Coating intact but browned
	0°	None	3.1	3.2		9.9	5.3	
	100°	None	0.9	- 4.9		4.8	- 4.7	Browned color
Freeze-Dried Pineapple Slices	0°	Amylose Laurate	4.1	4.8		10.5	8.1	
	100°	Amylose Laurate	2.6	0.6		7.4	1.5	
	0°	Acetoglyceride/ Soy Proteinate	2.4	-11.4		7.6	-11.6	Good color
	100°	Acetoglyceride/ Soy Proteinate	2.4	11.4		5.4	11.9	Browned color
	0°	None	4.6	7.7		4.9	10.1	
	100°	None	1.0	14.7		4.9	13.9	Color faded some samples browned
Freeze-Dried Fish Squares	0°	Ethylcellulose-Acetoglyceride	6.7	3.6		11.4	6.6	
	100°	Ethylcellulose-Acetoglyceride	4.3	- 2.6		7.0	- 2.5	Yellowish color
	0°	None	9.4	13.1		17.5	16.3	
	100°	None	3.3	0.6		7.4	2.5	Yellowish color

Table 27, page 4
(Continued)

THREE-MONTH STORAGE STUDY OF COATED FOODS

Food	Temperature °F	Coating	6 Week Evaluation % Moisture	6 Week Evaluation % Wt Change	6 Week Evaluation Remarks	3 Month Evaluation % Moisture	3 Month Evaluation % Wt Change	3 Month Evaluation Remarks
Shelled Brazil Nuts	0°	Gelatin	2.9	0.3	13. Meq peroxide/lb	4.4	0.5	3.3 meq peroxide/lb
	100°	Gelatin	1.5	- 1.1	25.3 Meq peroxide/lb	2.3	0	41.2 meq peroxide/lb Coating cracked
	0°	Soy Proteinate/ Acetoglyceride	1.5	0.3	3.7 Meq peroxide/lb	6.8	0.5	6.6 meq peroxide/lb
	100°	Soy Proteinate/ Acetoglyceride	1.1	- 0.9	10.7 Meq peroxide/lb	1.9	- 0.8	23.1 meq peroxide/lb
	0°	None	0.6	0.3	7.3 Meq peroxide/lb	1.8	0.8	5.9 meq p. oxide/lb
	100°	None	0.1	0.9	23.6 Meq peroxide/lb	1.6	5.7	59.9 meq peroxide/lb
Freeze-Dried Carrot Slices	0°	Soy Proteinate/ Acetoglyceride	5.3	2.0	201 Mg carotene/lb	9.4	3.6	149 mg carotene/lb
	100°	Soy Proteinate/ Acetoglyceride	2.7	- 2.6	39.9 Mg carotene/lb	4.9	- 2.3	18.6 mg carotene/lb Light yellow
	0°	Amylose Laurate/ Soy Proteinate/ Acetoglyceride	3.9	3.8	162 Mg carotene/lb	7.9	8.6	159 mg carotene/lb Good color
	100°	Amylose Laurate/ Soy Proteinate/ Acetoglyceride	1.5	- 5.9	29.8 Mg carotene/lb	5.3	- 5.4	9.5 mg carotene/lb
	0°	None	4.9	8.0	289 Mg carotene/lb	11.1	11.5	279 mg carotene/lb Faded to light yellow
	100°	None	3.4	- 2.9	56.8 Mg carotene/lb	5.8	- 2.9	3.6 mg carotene/lb No color, white
Freeze-Dried Peas	0°	Amylose Myristate Soy Proteinate	5.7	2.2		10.1	3.4	2.68 chlorophyll index Slt faded
	100°	Amylose Myristate Soy Proteinate	1.6	- 2.4	3.20 Chlorophyll index	4.3	- 2.2	2.88 chlorophyll index Slt faded
	0°	Soy Proteinate	4.0	2.4		5.5	7.4	3.35 chlorophyll index Slt faded
	100°	Soy Proteinate	2.4	1.4		4.9	2.0	3.39 chlorophyll index Slt faded
	0°	None	3.4	3.6	3.95 Chlorophyll index	8.8	7.5	3.63 chlorophyll index
	100°	None	2.8	1.8	3.42 Chlorophyll index	2.0	2.5	2.87 chlorophyll index Color faded

Table 27, page 5
(Continued)

THREE-MONTH STORAGE STUDY OF COATED FOODS

Food	Temperature °F	Coating	6 Week Evaluation			3 Month Evaluation		
			% Moisture	% Wt Change	Remarks	% Moisture	% Wt Change	Remarks
Freeze-Dried Straw-berries	0°	Polyglycerol Ester Acetoglyceride	3.2	3.9		12.4	6.8	
	100°	Polyglycerol Ester Acetoglyceride	2.2	- 2.1		4.2	- 2.1	Color faded
	0°	Polyglycerol Ester Monoglyceride	6.2	4.2		11.3	8.1	
	100°	Polyglycerol Ester Monoglyceride	1.9	.2		3.4	0.7	Color faded
	0°	None	15.7	8.4		9.8	13.5	
	100°	None	1.0	- 1.6		5.7	- 2.0	Color faded

TABLE 28

EVALUATION OF REHYDRATED COATED FOODS STORED FOR THREE MONTHS

Food	Storage Temperature °F	Coating	Evaluation
Air-Dried Apple Slices	0	None	Slightly dark, low flavor level
	100	None	Badly browned color and flavor
	0	Confectioners Coating Butter	Slightly dark, good aroma and flavor
	100	Confectioners Coating Butter	Good color, aroma and flavor
	0	Monoglyceride-Polyglycerol Ester	No apple flavor
	100	Monoglyceride-Polyglycerol Ester	Normal color and flavor
	0	Monoglyceride/Gelatin	Green apple aroma
	100	Monoglyceride/Gelatin	Slightly brown color, little apple flavor
Freeze-Dried Chicken	0	None	Fair aroma and flavor
	100	None	Slightly browned aroma, acceptable flavor
	0	Amylose Myristate/Soy Proteinate	Milk flavor, white color
	100	Amylose Myristate/Soy Proteinate	Mild chicken flavor, no off flavor, yellow color
	0	Polyglycerol Ester-Monoglyceride	Slight off flavor, light color
	100	Polyglycerol Ester-Monoglyceride	Normal odor and flavor, light color
	0	Polyglycerol Ester	Slightly sweet off flavor
	100	Polyglycerol Ester	Dark color, off flavor

Table 28, page 2
(Continued)

EVALUATION OF REHYDRATED COATED FOODS STORED FOR THREE MONTHS

Food	Storage Temperature °F	Coating	Evaluation
Freeze-Dried Sliced Pork	0	None	Normal color and flavor
	100	None	Very strong oxidized flavor and aroma, set green color
	0	Polyglycerol Ester-Monoglyceride	Normal color and flavor
	100	Polyglycerol Ester-Monoglyceride	Normal color and flavor
Freeze-Dried Peas	0	None	Normal color, no off flavor, little pea flavor
	100	None	Normal color, no off flavor, little pea flavor
	0	Amylose Myristate/Promine D	Normal color, fair pea flavor
	100	Amylose Myristate/Promine D	Normal color, fair pea flavor
	0	Soy Proteinate	Good aroma, color and flavor
	100	Soy Proteinate	Good aroma and color, fair flavor, some sweetness lost
Freeze-Dried Scrambled Egg	0	None	Normal color, acceptable flavor
	100	None	Browned color and flavor
	0	Ethylcellulose Acetoglyceride	Normal odor and color
	100	Ethylcellulose Acetoglyceride	Moderately browned color, odor and flavor
Freeze-Dried Fish Squares	0	None	Moderately browned
	100	None	Very brown
	0	Ethylcellulose Acetoglyceride	Normal odor and flavor
	100	Ethylcellulose Acetoglyceride	Slightly brown, no fishy odor

Table 28, page 3
(Continued)

EVALUATION OF REHYDRATED COATED FOODS STORED FOR THREE MONTHS

Food	Storage Temperature °F	Coating	Evaluation
Freeze-Dried Carrot Slices	0	None	Normal color and flavor
	100	None	Complete pigment loss, violet odor and flavor
	0	Acetoglyceride/Soy Proteinate	Slight pigment loss, slight violet odor
	100	Acetoglyceride/Soy Proteinate	Moderate pigment loss, slight violet odor
	0	Amylose Laurate/Soy Proteinate Acetoglyceride	Slight pigment loss
	100	Amylose Laurate/Soy Proteinate/ Acetoglyceride	Moderate pigment loss, violet odor and flavor
Freeze-Dried Sliced Pineapple	0	None	No pineapple flavor, color normal
	100	None	Slight browning
	0	Acetoglyceride/Soy Proteinate	Strong pineapple aroma, slight pineapple flavor
	100	Acetoglyceride/Soy Proteinate	Slight pineapple aroma, slight browning
	0	Amylose Laurate	Excellent color, good aroma and flavor
	100	Amylose Laurate	No aroma, almost no flavor, good color
Freeze-Dried Strawberries	0	None	Good color, fair aroma and flavor
	100	None	Green aroma
	0	Polyglycerol Ester-Monoglyceride	Fair aroma and flavor
	100	Polyglycerol Ester-Monoglyceride	Fair aroma, off flavor
	0	Polyglycerol Ester-Acetoglyceride	Good aroma and flavor
	100	Polyglycerol Ester-Acetoglyceride	Poor color, aroma and flavor

TABLE 29

REHYDRATION OF COATED FREEZE-DRIED FOODS STORED FOR THREE MONTHS

Food	Storage Temperature °F	Coating	Water Absorption % of Dry Weight			Rate of Rehydration g H_2O/100g Dry Product/min	
			5 min	10 min	15 min	5 min	15 min
Chicken	0°	None	114	116	125	22.8	8.4
	100°	None	127	135	134	25.4	8.9
	0°	Amylose Myristate/Soy Proteinate	104	113	114	20.8	7.6
	100°	Amylose Myristate/Soy Proteinate	102	108	108	20.4	7.2
	0°	Polyglycerol Ester	53	62	67	10.6	4.5
	100°	Polyglycerol Ester	82	88	-	16.4	8.8 (10 min)
	100°	Polyglycerol Ester-Monoglyceride	108	121	116	21.6	7.7
Scrambled Eggs	0°	None	180	210	232	36.0	15.4
	100°	None	198	214	241	39.6	16.0
Sliced Pork	0°	None	81	84	84	16.2	5.6
	100°	None	101	116	113	20.2	13.5
	0°	Polyglycerol Ester-Monoglyceride	82	88	86	16.4	5.7
	100°	Polyglycerol Ester-Monoglyceride	59	69	71	11.8	7.9
Pineapple Slices	0°	None	113	172	183	22.6	12.2
	100°	None	158	198	225	31.6	15.0
	0°	Amylose Laurate	61	98	127	12.2	8.5
	100°	Amylose Laurate	90	140	168	18.0	11.2
	0°	Acetoglyceride/Soy Proteinate	88	-	115(12 min)	17.6	7.7 (20 min)
	100°	Acetoglyceride/Soy Proteinate	57	112	152	11.4	10.1

Table 29, page 2
(Continued)

REHYDRATION OF COATED FREEZE-DRIED FOODS STORED FOR THREE MONTHS

Food	Storage Temperature °F	Coating	Water Absorption % of Dry Weight			Rate of Rehydration g H_2O/100g Dry Product/	
			5 min	10 min	15 min	5 min	15 min
Fish Squares	0°	None	238	224	0	47.6	22.4 (10 min)
	100°	None	298	283	-	59.6	28.3 (10 min)
	100°	Ethylcellulose Acetoglyceride	233	208	218	46.6	14.5
Carrot Slices	0°	None	296	365	382	59.2	25.4
	100°	None	370	445	495	74.0	33.0
	0°	Amylose Laurate/Soy Proteinate/ Acetoglyceride	222	268	305	44.4	20.3
	0°	Acetoglyceride/Soy Proteinate	135	134	121	26.4	12.7
Freeze-Dried Peas	0°	None	264	280	304	52.8	20.2
	100°	None	310	329	342	62.0	22.8
	0°	Amylose Myristate/Soy Proteinate	190	246	264	38.0	17.6
	100°	Amylose Myristate/Soy Proteinate	165	247	282	33.0	18.8
Freeze-Dried Strawberries	0°	None	246	248	-	49.2	24.8 (10 min)
	100°	None	342	333	-	68.4	33.3 (10 min)
	0°	Polyglycerol Ester-Monoglyceride	205	204	-	41.0	20.4 (10 min)
	100°	Polyglycerol Ester-Monoglyceride	235	231	-	47.0	23.1 (10 min)

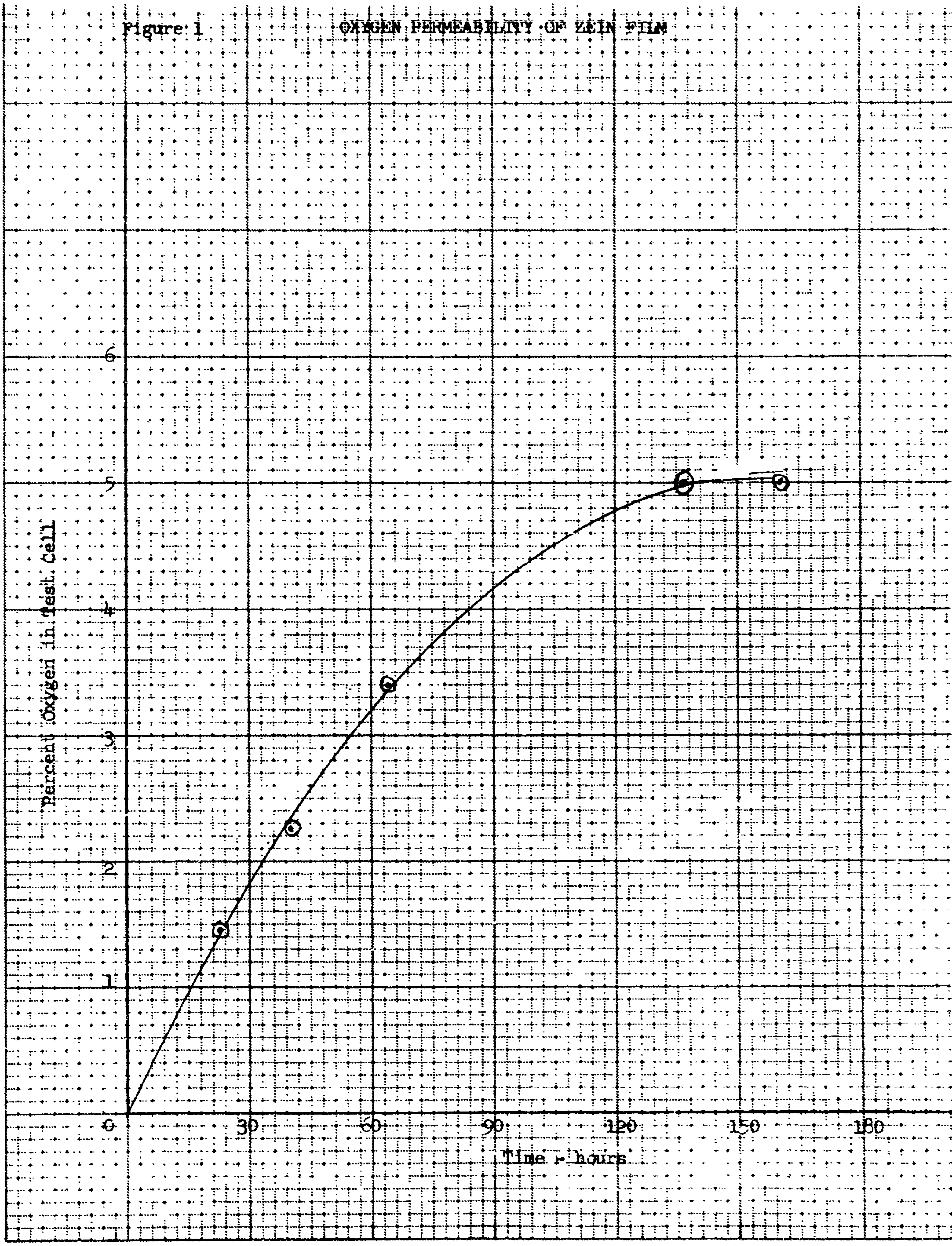
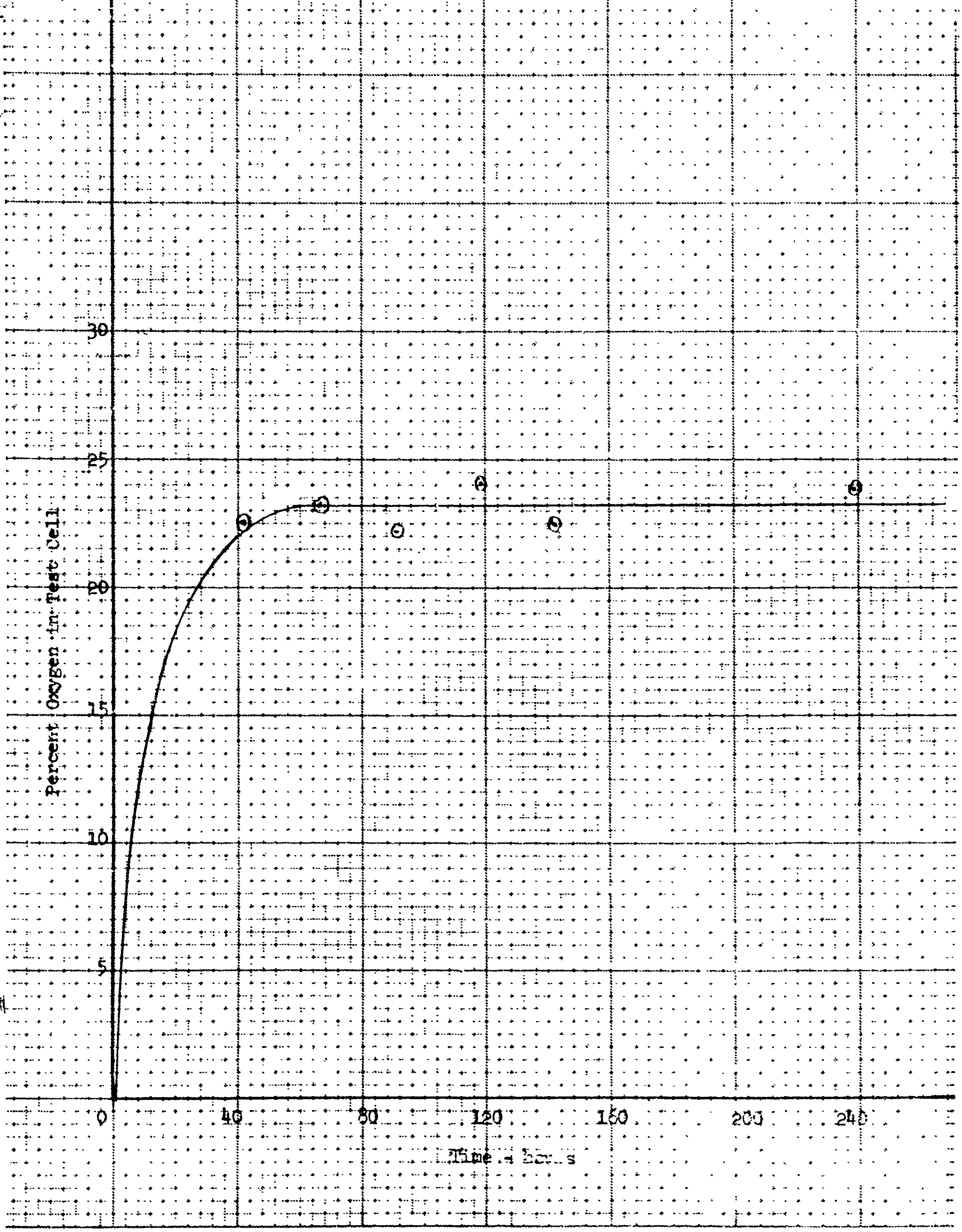


Figure 1
OXYGEN PERMEABILITY OF ZEIN FILM
Percent Oxygen in Test Cell
Time - hours
0
1
2
3
4
5
6
30
60
90
120
150
180

Figure 2 OXYGEN PERMEABILITY OF GLUTEN FILM



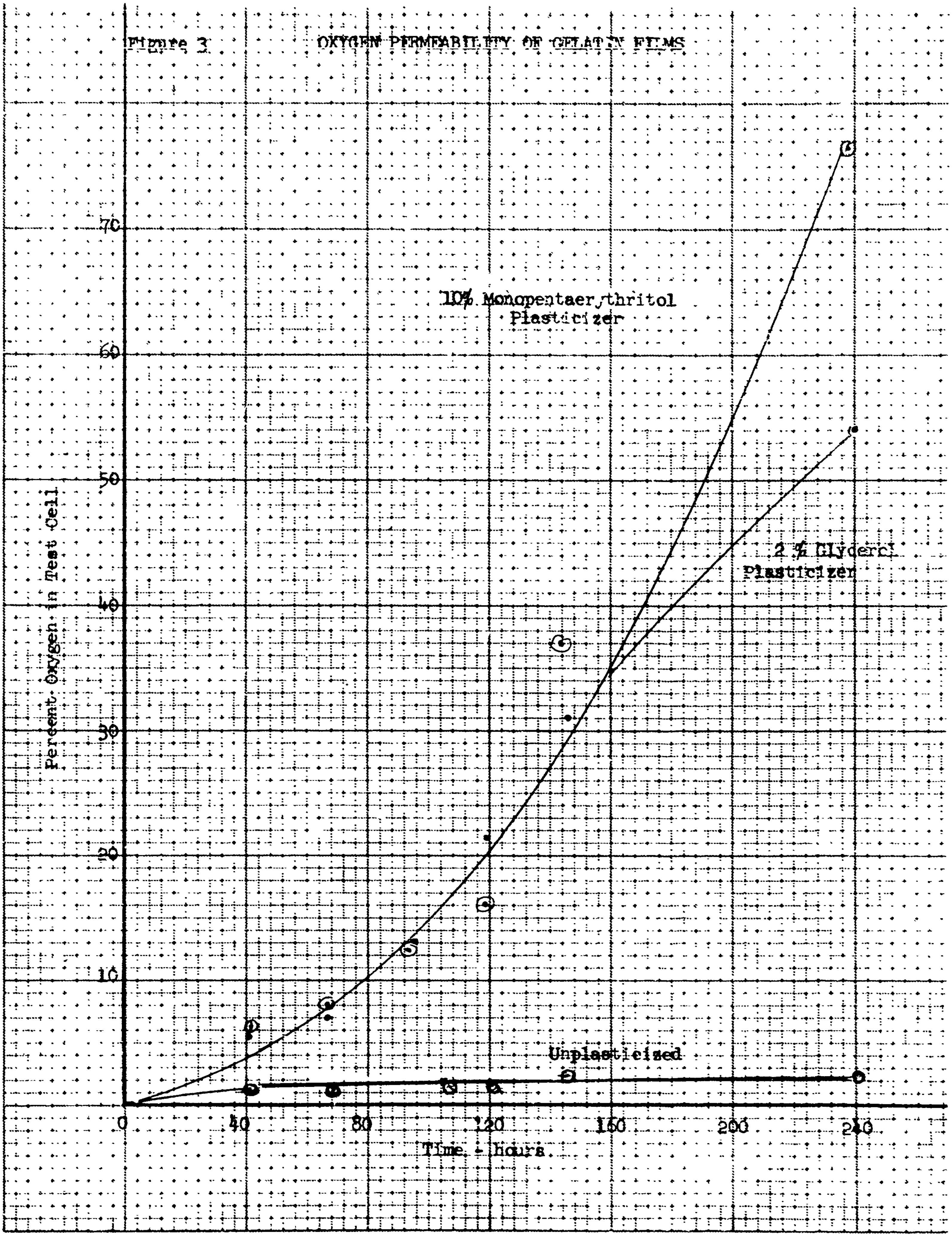


Figure 3
OXYGEN PERMEABILITY OF GELATIN FILMS
10% Monopentaerythritol
Plasticizer
2 % Glycerol
Plasticizer
Unplasticized
Percent Oxygen in Test Cell
Time - hours
0
40
80
120
160
200
240
10
20
30
40
50
60
70

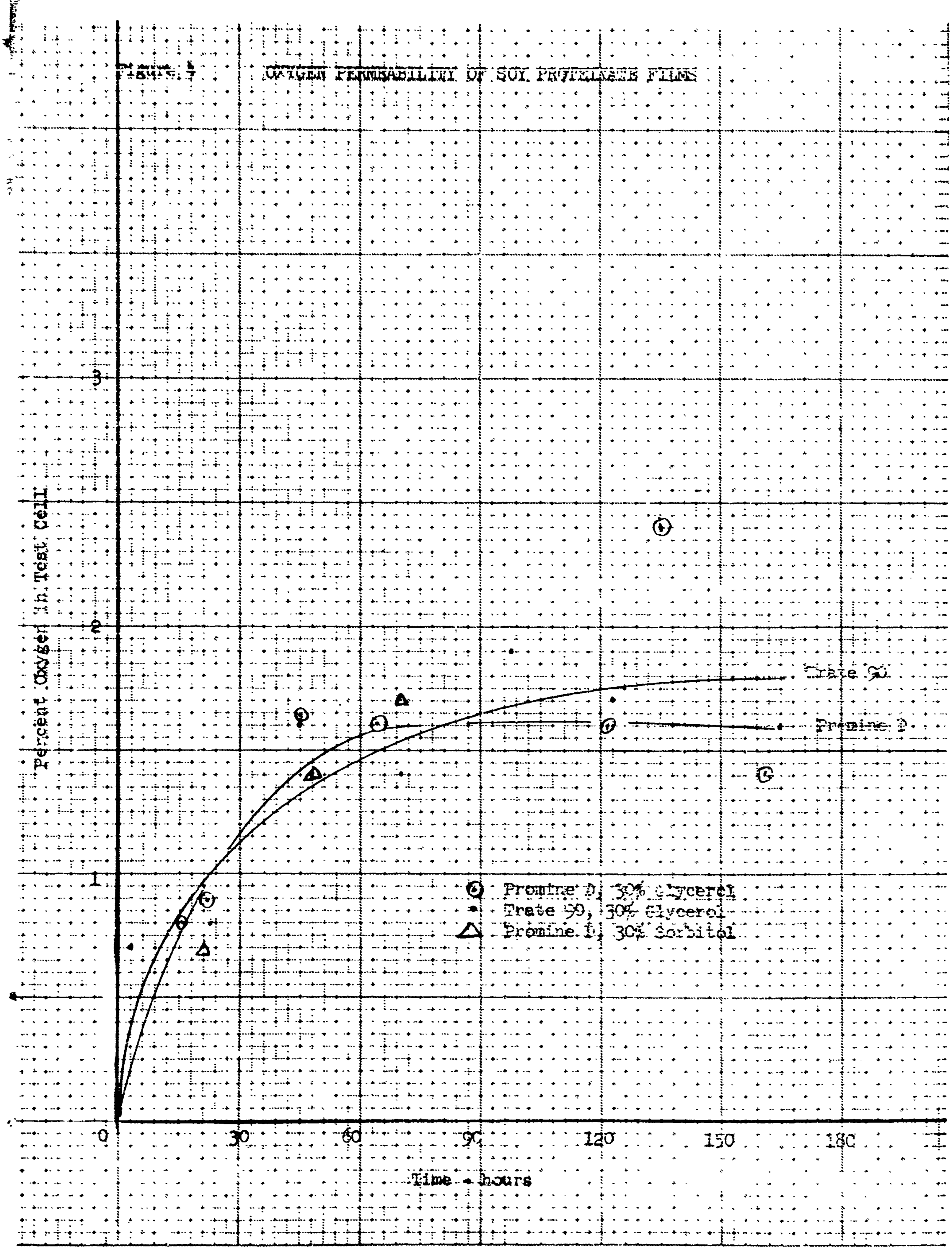
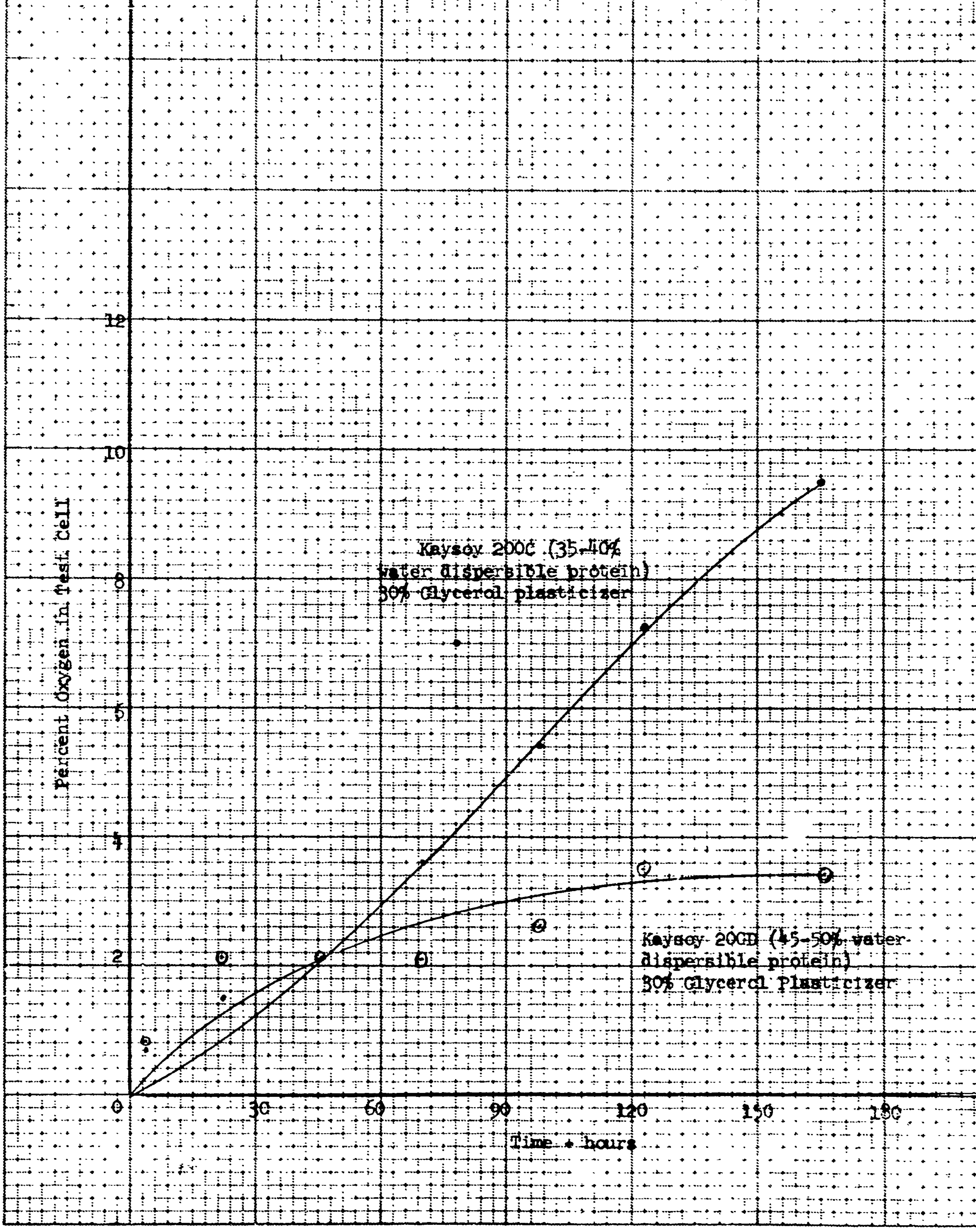

OXYGEN PERMEABILITY OF SOY PROTEINATE FILMS
Percent Oxygen in Test Cell
3
2
1
0
30
60
90
120
150
180
Time - hours
Trate 90
Promine D
Promine D, 30% Glycerol
Trate 90, 30% Glycerol
Promine D, 30% Sorbitol

Figure 5 OXYGEN PERMEABILITY OF 50% PROTEIN SOY FLOURS



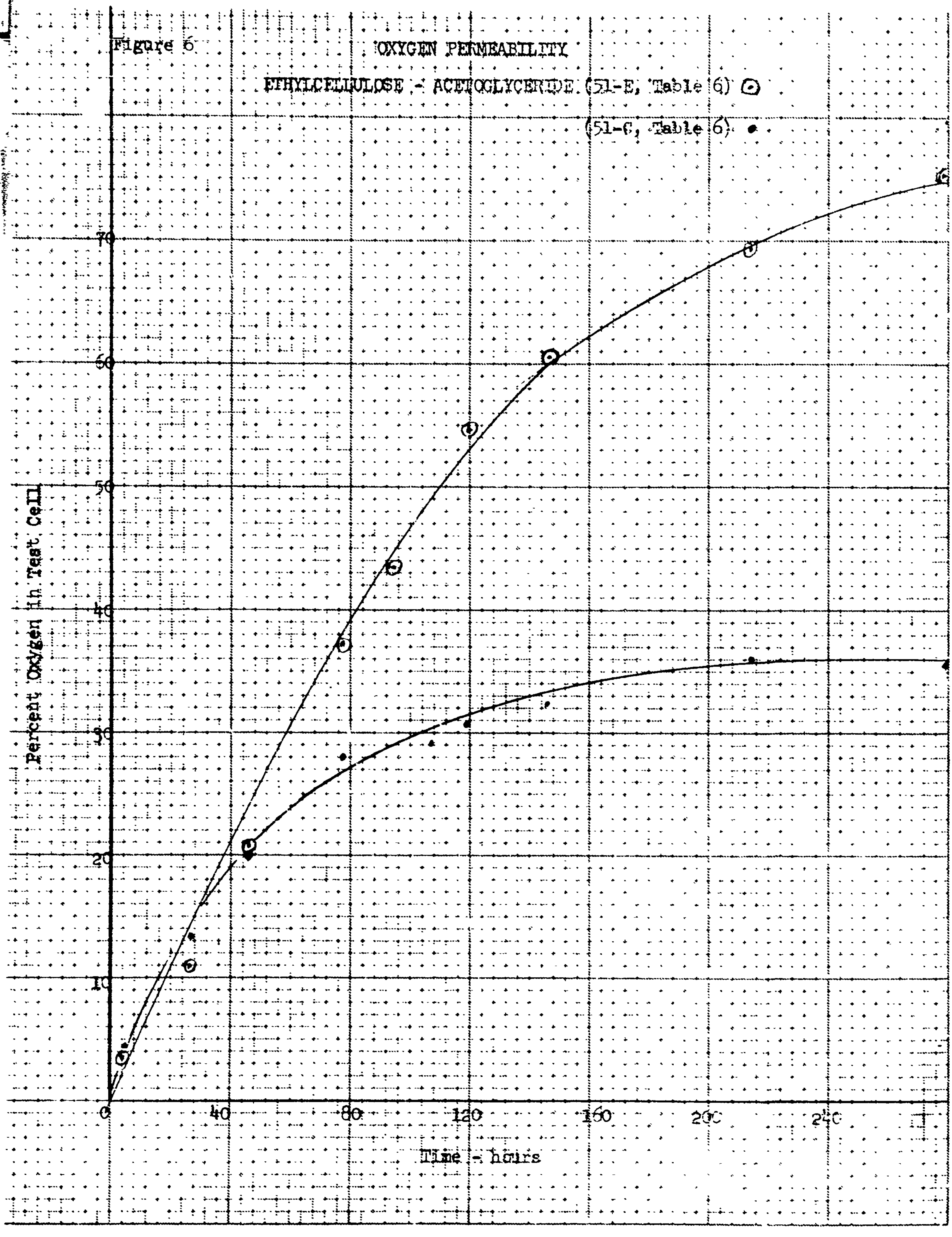


Figure 6
OXYGEN PERMEABILITY
ETHYLCELLULOSE - ACETOGLYCERIDE (51-E, Table 6)
(51-C, Table 6)
Percent Oxygen in Test Cell
Time - hours
0
10
20
30
40
50
60
70
0
40
80
120
160
200
240

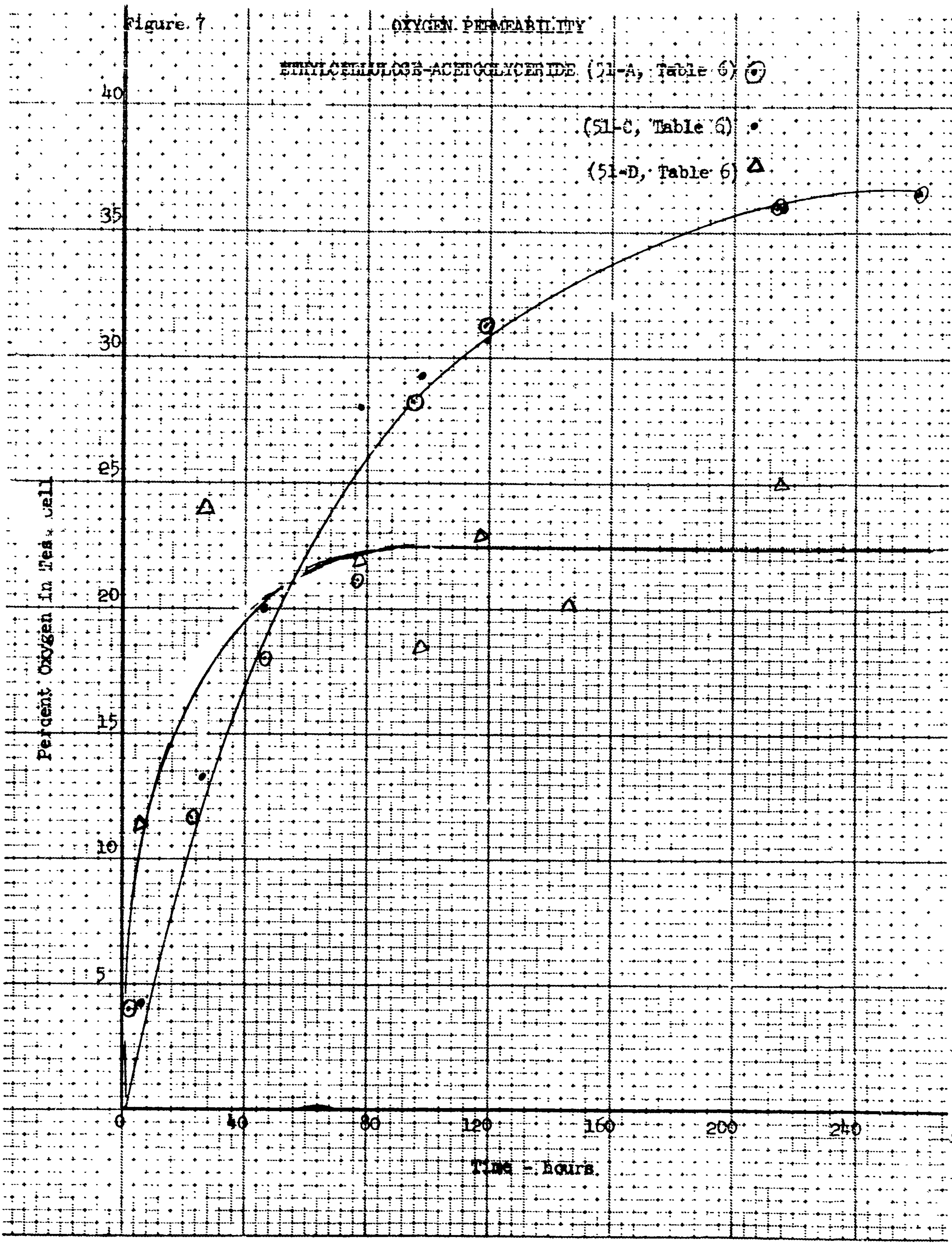


Figure 7
OXYGEN PERMEABILITY
ETHYLCELLULOSE-ACETOGLYCERIDE (51-A, Table 6)
(51-C, Table 6)
(51-D, Table 6)
Percent Oxygen in Test Cell
Time - Hours
0
5
10
15
20
25
30
35
40
80
120
160
200
240

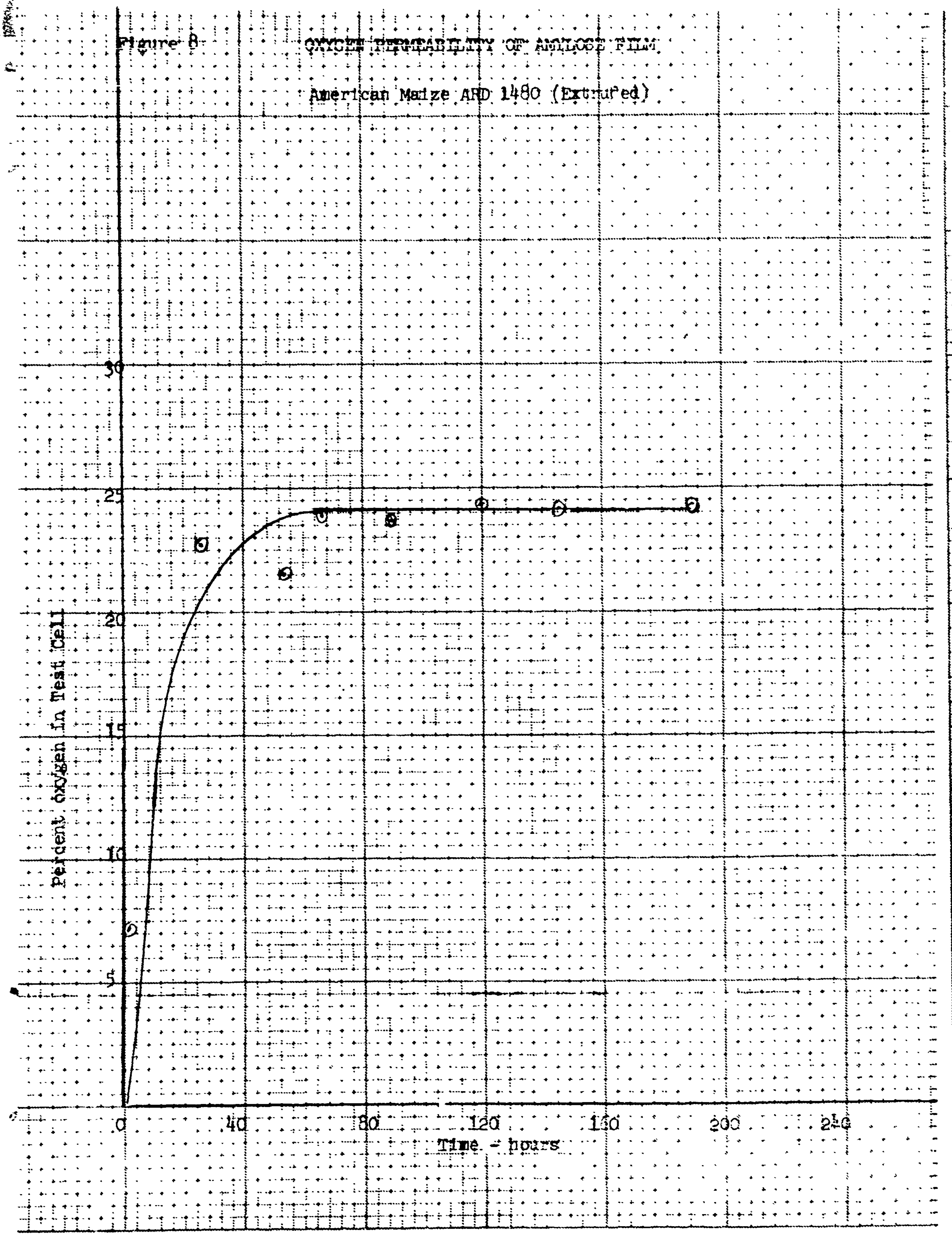


Figure 8 OXYGEN PERMEABILITY OF AMYLOSE FILM

American Maize ARD 1480 (Extruded)

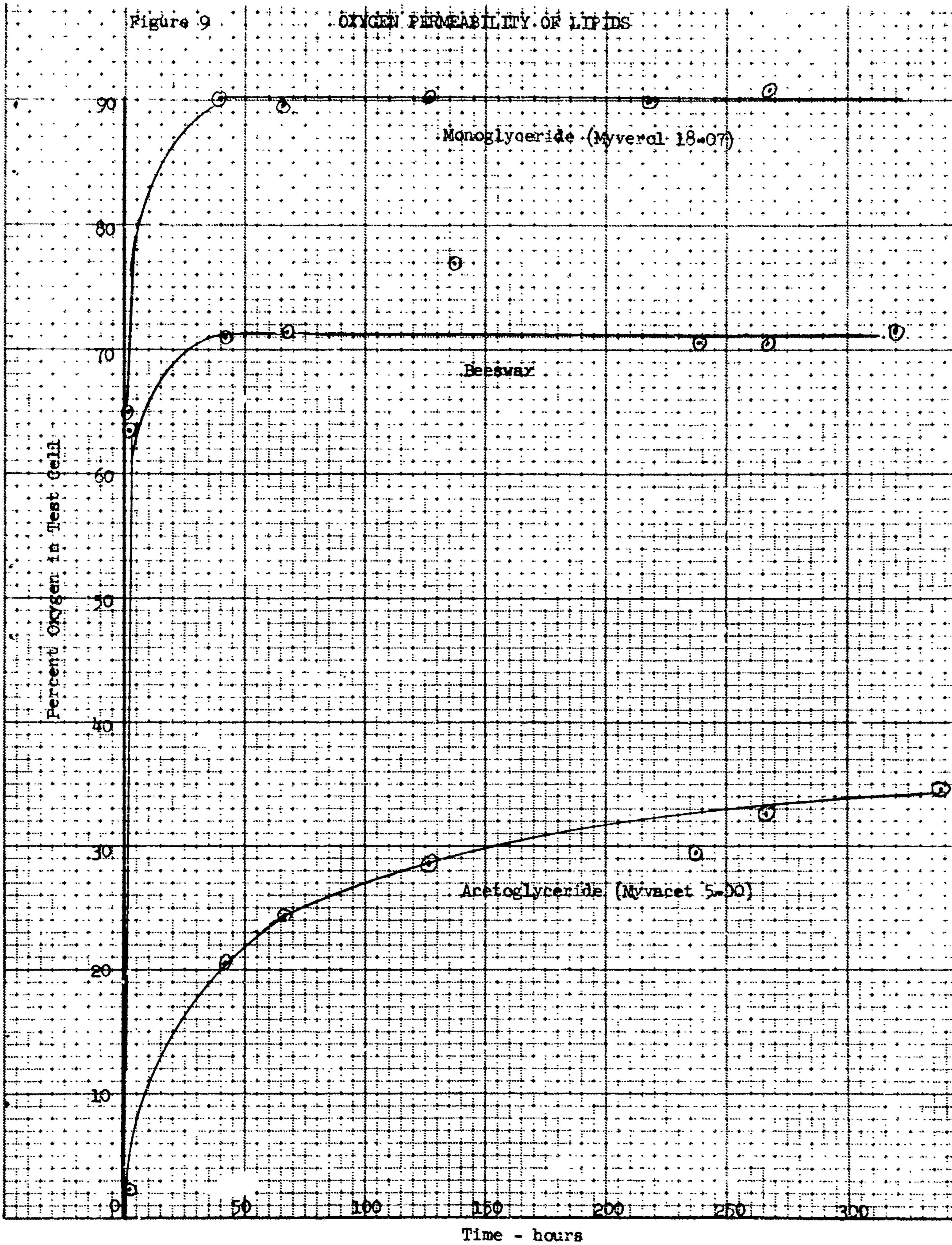


Figure 9
OXYGEN PERMEABILITY OF LIPIDS
Monoglyceride (Myveral 18-07)
Beeswax
Acetoglyceride (Myvacet 5-00)
Percent Oxygen in Test Cell
Time - hours
90
80
70
60
50
40
30
20
10
0
50
100
150
200
250
300

FIGURE 10 EQUILIBRIUM RELATIVE HUMIDITY

SODIUM SOY PROTEINATE FILM

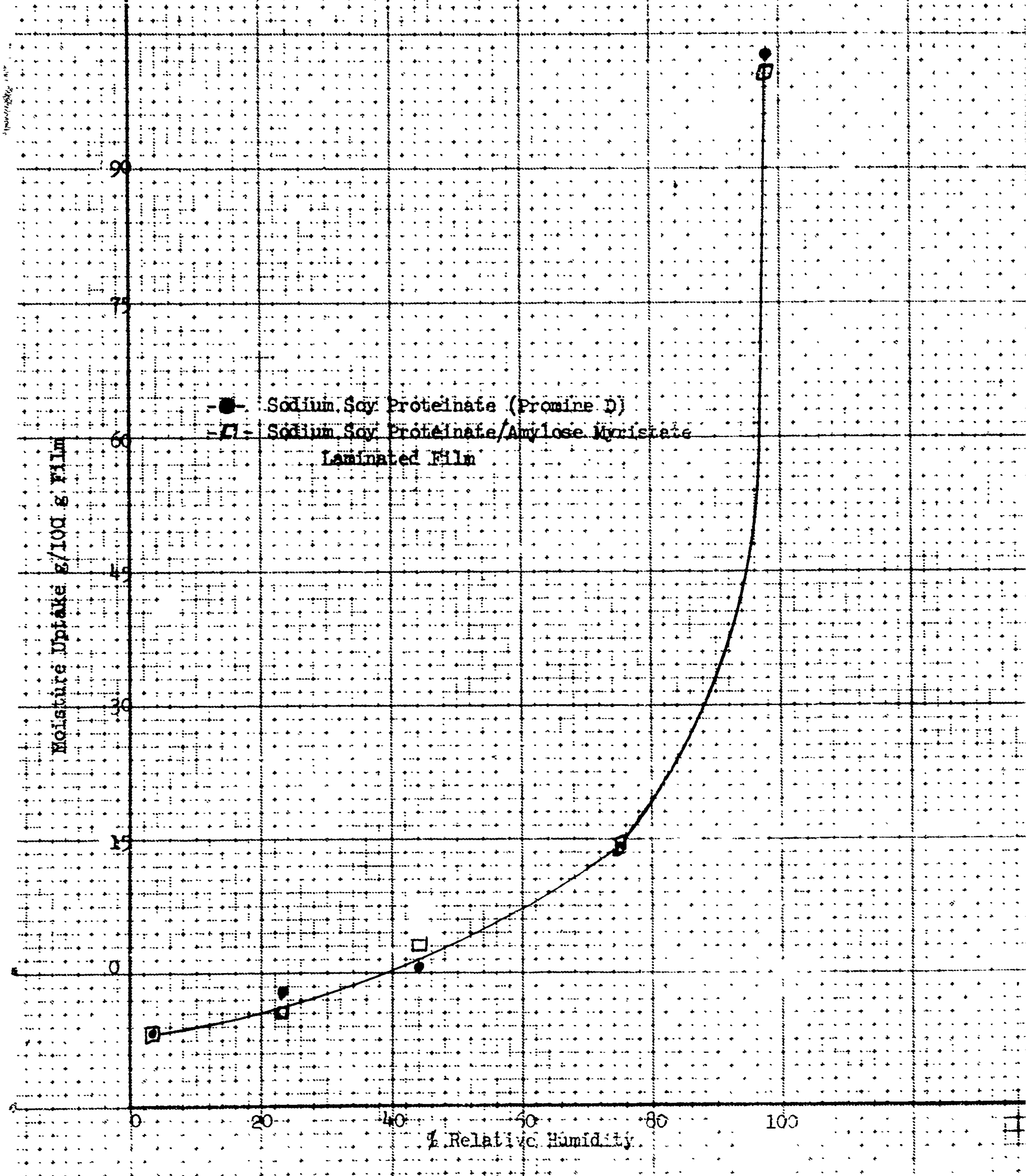


FIGURE 11 EQUILIBRIUM RELATIVE HUMIDITY

POLYGLYCEROL ESTERS AND MONOGLYCERIDES

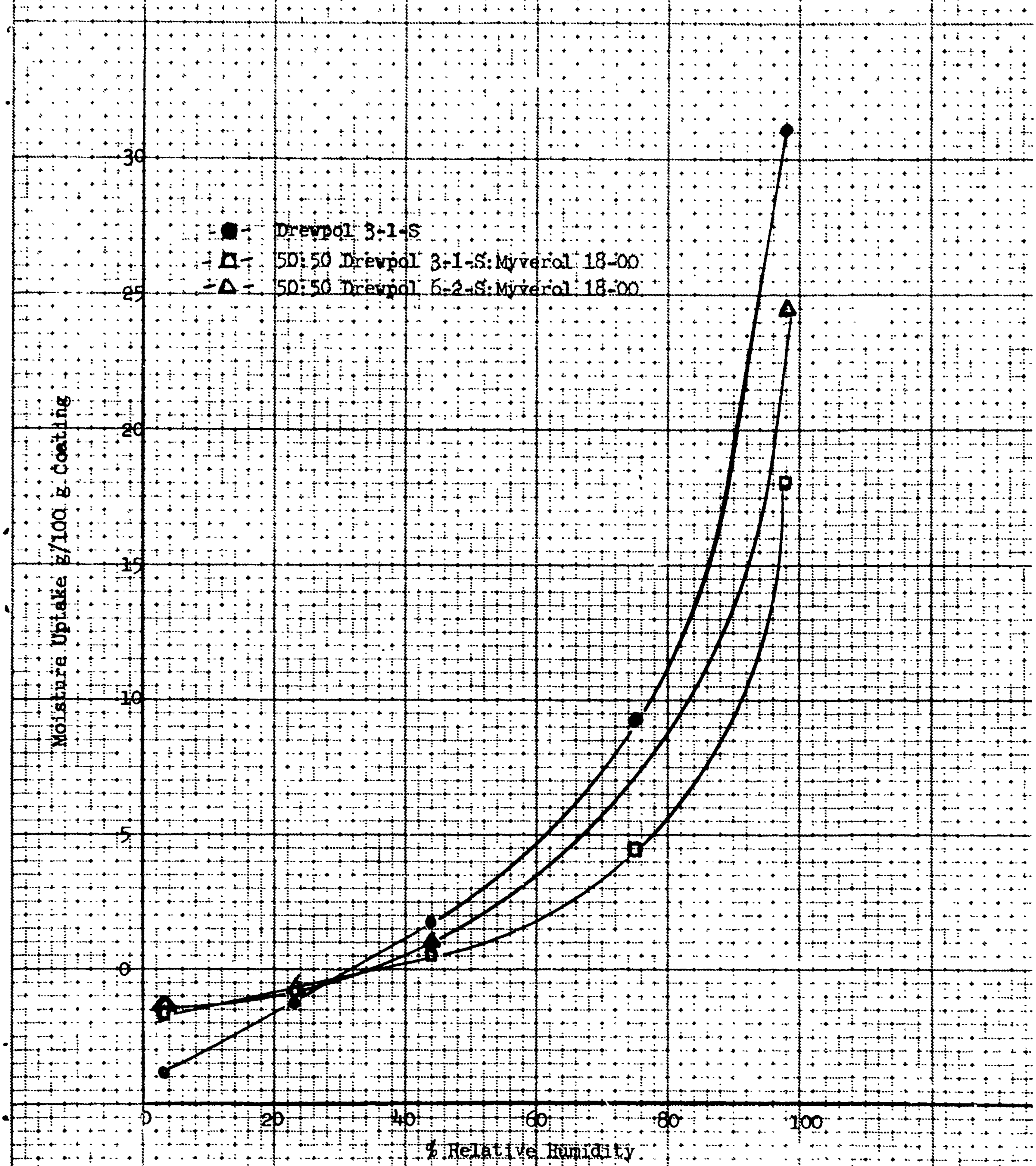


FIGURE 12

EQUILIBRIUM RELATIVE HUMIDITY
POLYGLYCEROL ESTERS AND ACETOGLYCERIDES

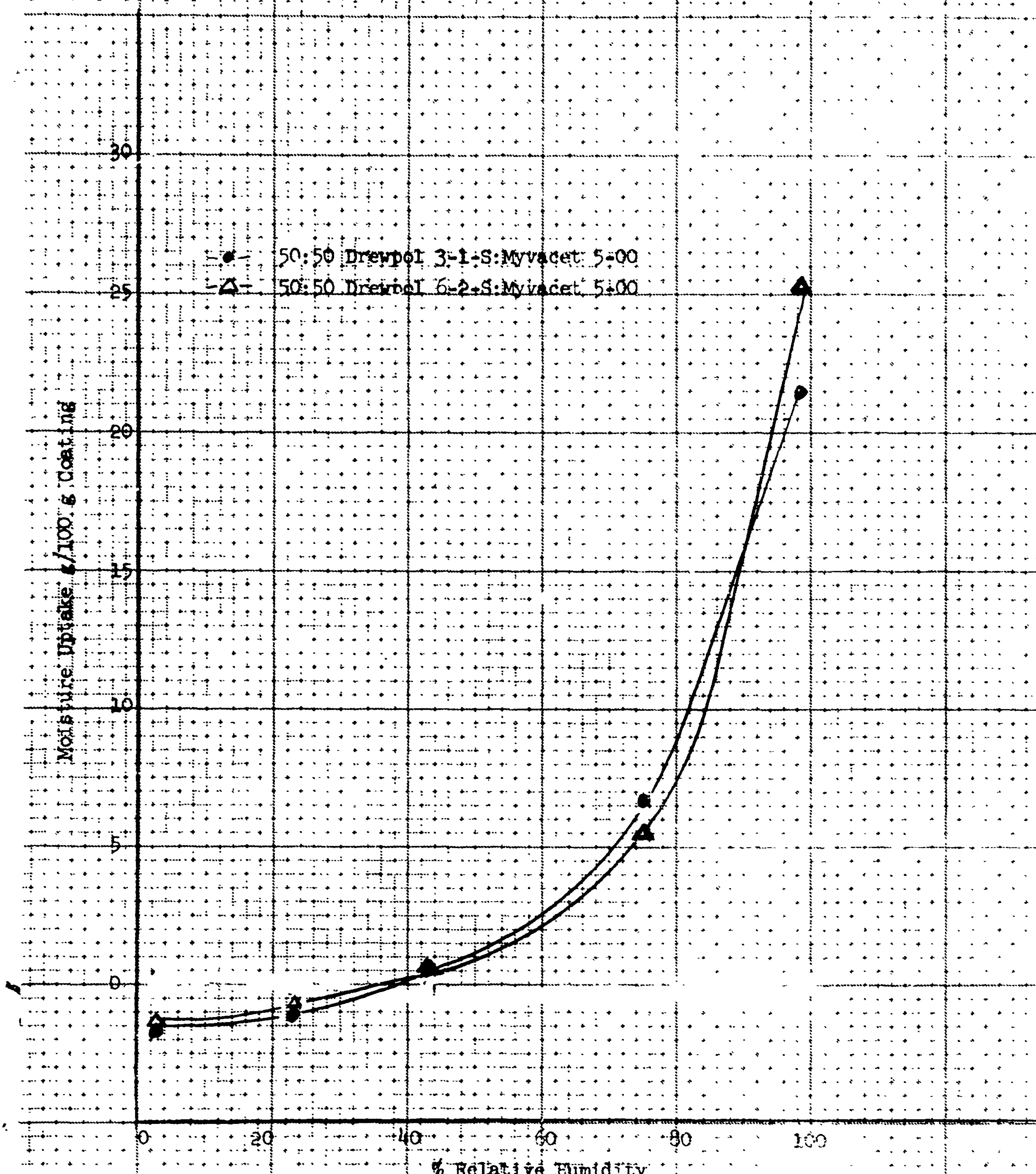


FIGURE 13 EQUILIBRIUM RELATIVE HUMIDITY
TRIGLYCERIDE AND ACETOGLYCERIDE

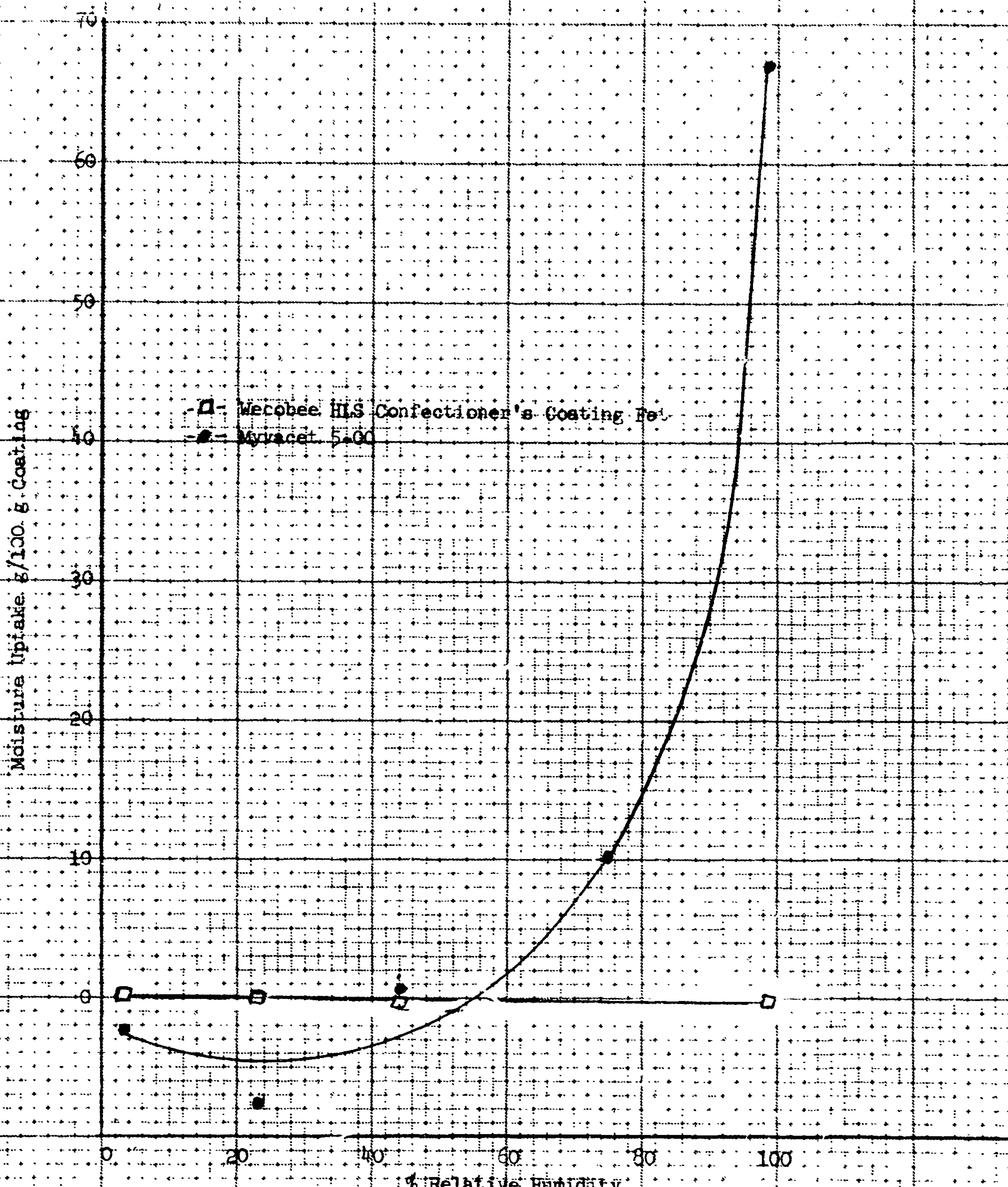
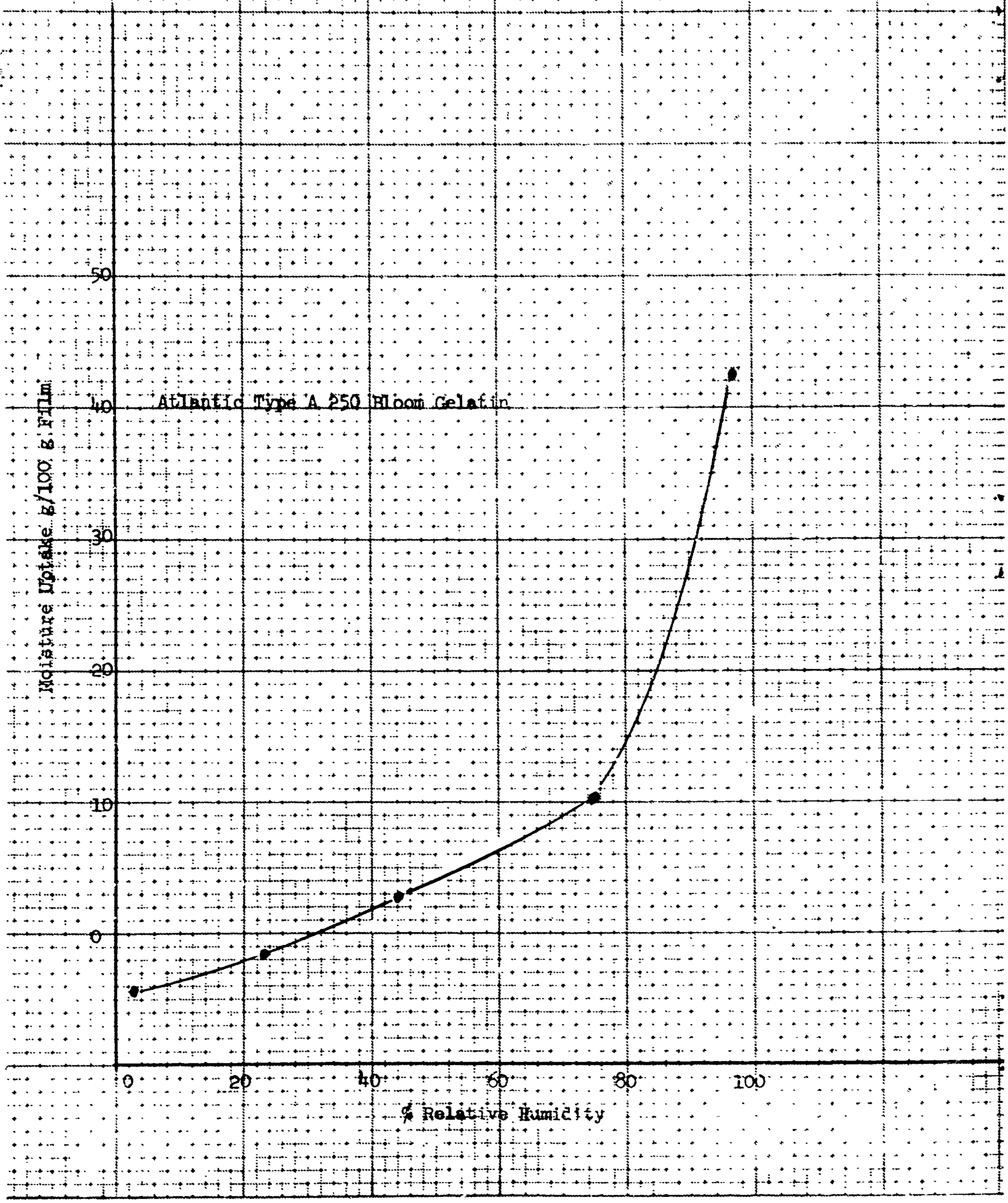


FIGURE 14 EQUILIBRIUM RELATIVE HUMIDITY
UNPLASTICIZED GELATIN



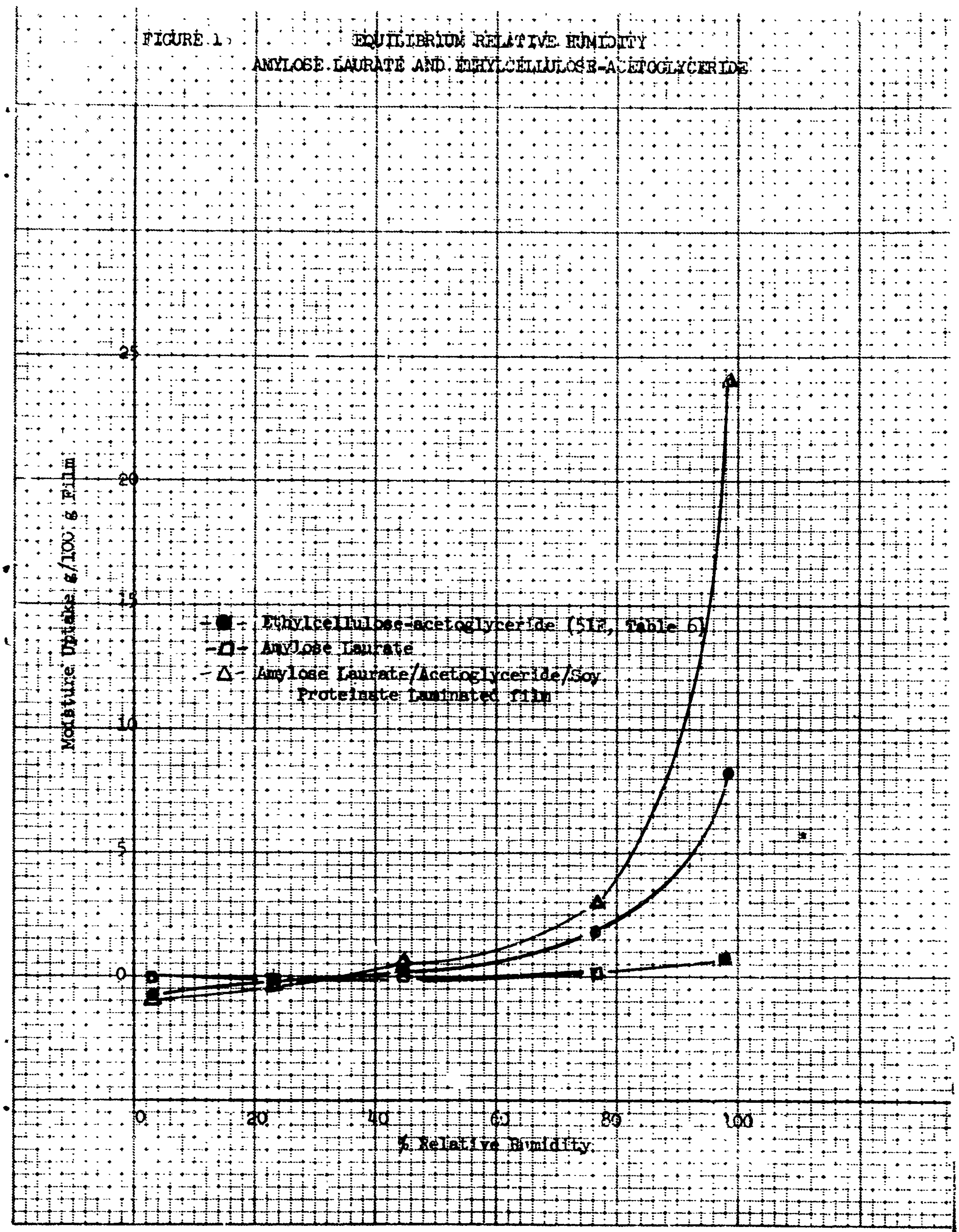


FIGURE 1.
EQUILIBRIUM RELATIVE HUMIDITY
AMYLOSE LAURATE AND ETHYLCELLULOSE-ACETOGLYCERIDE
Moisture Uptake g/100 g Film
25
20
15
10
5
0
Ethylcellulose-acetoglyceride (51E, Table 6)
Amylose Laurate
Amylose Laurate/Acetoglyceride/Soy Proteinate Laminated Film
0
20
40
60
80
100
% Relative Humidity

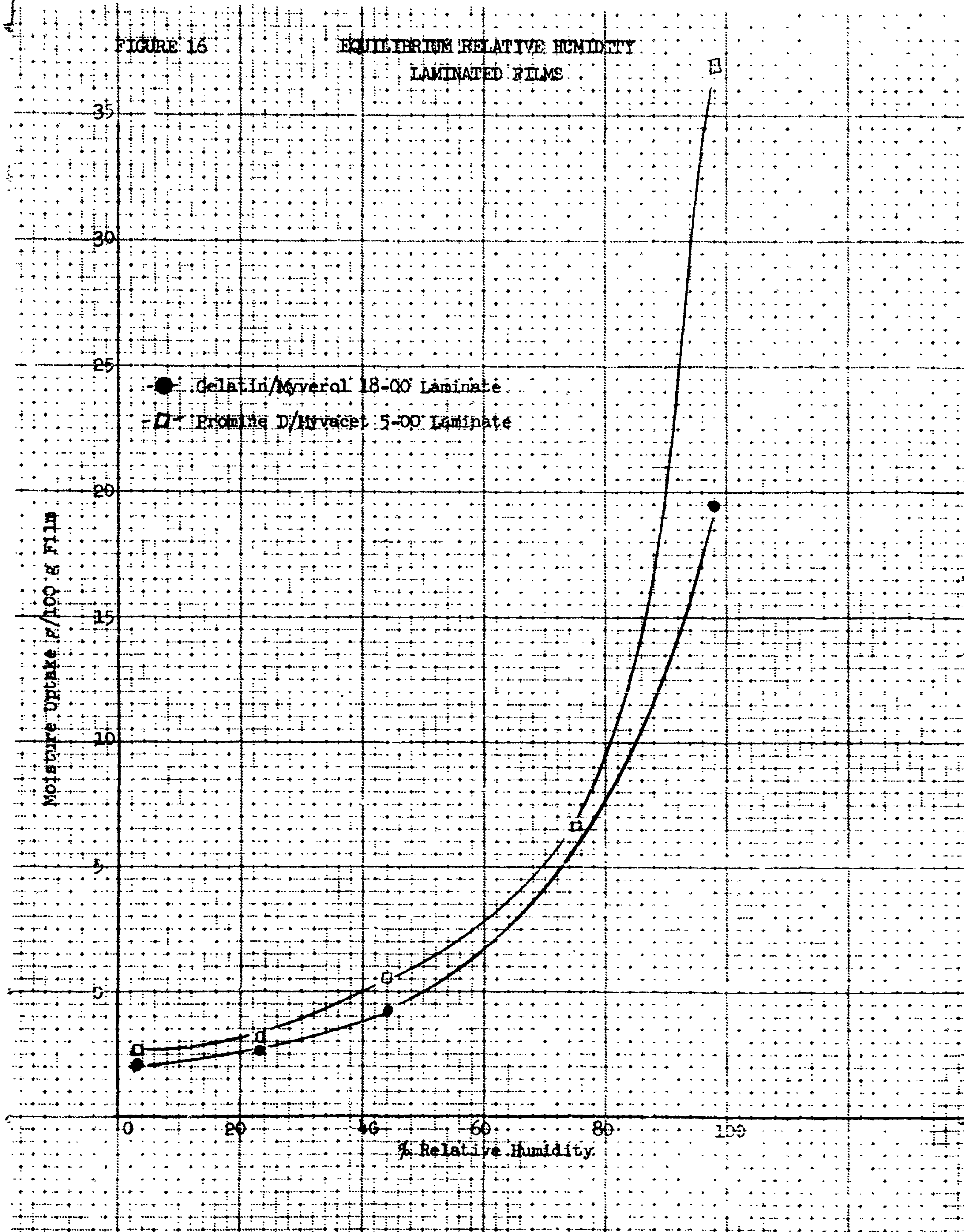


FIGURE 16
EQUILIBRIUM RELATIVE HUMIDITY
LAMINATED FILMS
Gelatin/Myverol 18-00 Laminate
Promine D/Myvacet 5-00 Laminate
Moisture Uptake g/100 g Film
% Relative Humidity
35
30
25
20
15
10
5
0
0
20
40
60
80
100

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13 ABSTRACT

Studies are presented on the development of edible barrier materials, their application to dehydrated foods and evaluation under accelerated storage conditions, effects of atmospheric oxygen and moisture, fragmentation and abrasion, and attack by microorganisms.

The most effective coating materials include hot melts of acetoglycerides and ethylcellulose; mixtures of monoglycerides and polyglycolesters; protein films including soy proteinate and gelatin; fatty esters of amylose; monoglycerides; hard fats; and combinations of these materials in the form of laminates or mixtures.

Approved chemical preservatives, including sorbic acid, potassium sorbate, methyl and propyl p-hydroxybenzoates were effective in retarding mold growth when incorporated in coating formulations.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Preparation(Formulation)	8					
Coatings	2		10		10	
Food	2		10		10	
Food Bars	4		9		9	
Compressed foods	4		9		9	
Protection	4				8	
Prevention			8			
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Erosion			3			
Moisture					3	
Oxygen					3	
Fungi			3			

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